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PART I (No. 233).

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PART II (No. 234).

(Issued 15th May, 1931.)

PART III (No. 235).

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PART IV (No. 236).

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THE GASTEROMYCETES OF AUSTRALASIA. X.

THE PHALLALES, PART I.

By G. H. CUNNINGHAM,
Mycologist, Plant Research Station, Palmerston North, N.Z.

(Plates i-ii.)

[Read 25th March, 1931.]

This Order comprises a group of fungi characterized as a rule by the bizarre shape, bright colour and fetid odour of the spore-bearing receptacle. Two essential groups of tissues are common to all of them: (1) the peridium, a membrane enclosing the receptacle until maturity is reached; and (2) the receptacle, a pseudoparenchymatous structure upon which is borne the gleba or spore-mass. The fact that the hymenium is enclosed until maturity has led to the Order being placed in the Gasteromycetes.

Morphology of the Mature Plant.

Peridium.—In immature plants this structure appears as a globose or obovate structure of three layers (two in *Claustula*): an outer, furfuraceous or smooth, usually white membrane (the exoperidium); a middle, thick and gelatinous layer (the mesoperidium); and an inner, thin and tough white membrane (the endoperidium). Collectively these layers form in the unexpanded plant the outer layer of the "egg", and enclose the receptacle and gleba. At maturity the peridium ruptures from the apex downwards, splitting into several lobes, exposing the receptacle, and remains at the base of the latter, forming a stellate supporting cup or "volva". The receptacle is always free within the volva (save in *Claustula*, where it is at first attached by a fine basal strand), being held in position in expanded plants by lateral pressure of the receptacle against the cupulate base and edges of the lobes. The peridium is practically identical in all genera, consequently it is upon the diversity of structure exhibited by the receptacle that the numerous genera and species have been erected.

Receptacle.—In essentials this structure consists of a pseudoparenchymatous, usually coarsely chambered tissue, upon some modified portion of which is carried the gleba. It develops within the peridium, and as it approaches maturity, the receptacle is thrown into folds, the cells become strongly turgescent, and pressure is exerted upon the apex of the peridium, causing its rupture. The receptacle continues to expand, until finally it assumes a size considerably in excess of the peridium. Expansion is rapid, for in *Aseroe rubra* the plant is fully developed within one or two hours after rupture of the peridium. The gleba, borne on some portion of the receptacle, appears as a mucilaginous, olivaceous, fetid mass containing countless numbers of exceedingly minute, smooth, elliptical spores.

The most primitive type of receptacle occurs in the genus *Claustula*, and consists of a cellular, hollow, apparently indehiscent structure, not unlike an inverted hen's egg, bearing the gleba on its inner surface. As it is a somewhat anomalous genus (being apparently indehiscent), discussion concerning it will be deferred until the systematic portion of this work. The next most primitive type of receptacle occurs in the genus *Mutinus*, and consists of a cylindrical hollow stem, upon the modified apical portion of which is borne the gleba. In the related genus *Floccomutinus*, the gleba is carried upon a loose network (the fore-runner of the pileus) at the apex of a similar stem; and in *Ithyphallus* and *Dictyophora* it is borne upon an additional structure, the pileus. This is a campanulate, pseudoparenchymatous tissue attached to the apex of a stem similar to that of *Mutinus*, and may be rugulose or reticulated. *Dictyophora* possesses an additional structure in the form of a pendent, pseudoparenchymatous membrane termed an indusium, which hangs beneath the pileus around the stem; and its presence would show that this is the most highly developed genus of those present in the family Phallaceae, to which these genera (save *Claustula*) belong.

In many genera of a second family included in the Order (the Clathraceae) a stem is present as in *Mutinus*, but the apex is modified to form various arms, which may be organically united apically, as in *Anthurus*; united by a membrane, as in *Mycopharus*; apically free but connivent, as in *Lysurus*; or horizontally expanded, as in *Aseroe*. In other genera the stem may be modified apically to support a small spherical latticed structure, as in *Simblum*; reduced to a small basal cylinder supporting several columns, in turn supporting a latticed structure, as in *Colus*; suppressed altogether, the receptacle then appearing clathrate, as in *Clathrus*, or as several simple columns apically united, but basally free, as in *Linderia*, *Blumenavia* and *Laternea*.

The receptacle is usually coloured in some conspicuous manner. Thus in *Mutinus* the stem-like receptacle may be yellow, orange, or red; in *Clathrus* the latticed receptacle may be red or white; and in *Dictyophora multicolor* the stem is lemon-yellow, the pileus orange, indusium and volva pink, and mycelium purple.

The bright colours, bizarre shape of the receptacle, strongly fetid odours and mucilaginous nature of the gleba are obviously developed to attract insects and thus secure rapid dispersal of the spores. This is supported by the fact that flies and other insects are readily attracted to expanded plants, and that the faeces of insects fed on the gleba contain numerous spores which germinate readily (Fulton, 1889).

The economic importance of the Order is slight. Cobb (1906) reported that *Ithyphallus rubicundus* was the cause of a root-rot of sugar-cane in Hawaii; and Carne (1922) recorded *Aseroe rubra* upon roots of *Cynodon Dactylon* L. Occasional records have been published showing that certain species possess poisonous properties. Thus Farlow (1890) recorded that *Linderia columnata* killed pigs within 12 or 15 hours after eating; and Colenso (1883) claimed that *Aseroe rubra* destroyed cats in the Woodville (N.Z.) district. But one species, *Clathrus cibarius*, has been claimed to be edible. But this is open to doubt, as I have shown elsewhere (1922).

The Order is usually divided into two families, the Phallaceae and the Clathraceae, differing in details of development and in the structure of the receptacle. Opinions are divided as to which is the more primitive family. Lohwag (1924) and others considered that the Phallaceae were derived from the

Clathraceae. This is supported by the fact that in the Phallaceae there are present in certain genera additional structures (as the pileus in *Ithyphallus* and *Dictyophora*; indusium in *Dictyophora*) not found in the Clathraceae; but is negatived by the fact that genera such as *Mutinus* are obviously more primitive than any occurring in the Clathraceae, and by the more complex nature of the receptacle of many genera of the latter family. It is probable that each has had a separate origin in time from some *Mutinus*-like ancestor, and that development has proceeded on the one hand to considerable alteration of the receptacle, leading to the evolution of the higher genera of the Clathraceae (as represented by *Laternea*, *Aseroe* and *Clathrus* of the tribes Columnateae, Stellateae and Clathrateae respectively); and on the other to the production of the characteristic pileus (and indusium) of the Phallaceae.

To these two families, I would add a third, the Claustulaceae, to contain the interesting genus *Claustula*.

The following diagram illustrates my views on the probable origin of the known genera, and shows, too, the possible evolution of the three tribes of the Clathraceae.

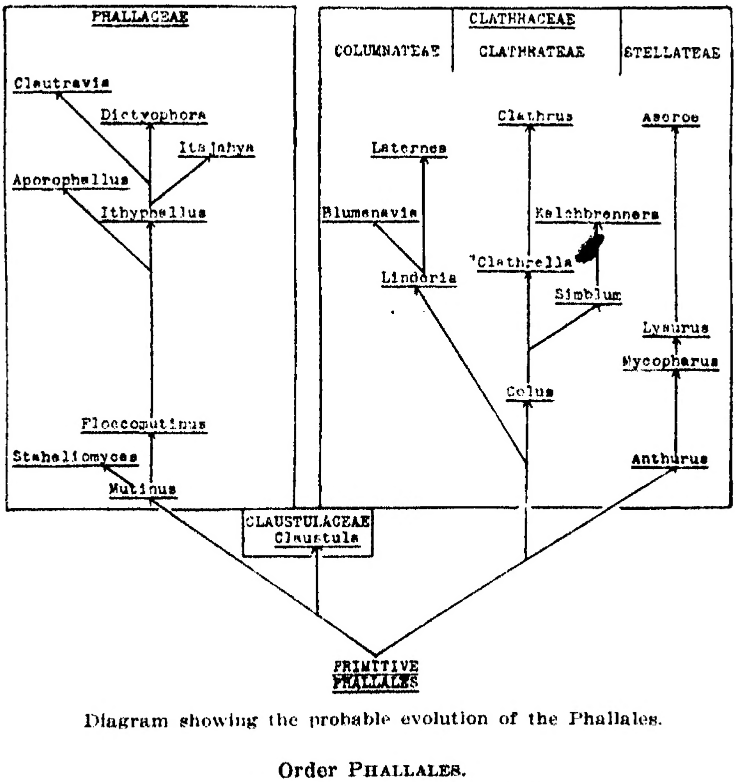

Diagram showing the probable evolution of the Phallales.

Order Phallales.

Plant at first consisting of a 2- or 3-layered peridium enclosing the receptacle and gleba. Peridium rupturing apically, remaining at the base of the receptacle as the volva. Receptacle pseudoparenchymatous, bearing the gleba on some portion of its surface. Gleba at maturity mucilaginous, olivaceous and usually fetid.

I have emended the Order to contain the three following families:

I. Family PHALLACEAE: Receptacle stipitate; cylindrical or fusoid, with or without an apical campanulate pileus and an indusium; gleba borne on the exterior of the pileus, or directly upon the modified apical portion of the stem.

II. Family CLATHRACEAE: Receptacle stipitate or sessile; clathrate, of simple columns united at their apices but basally free, or stipitate and divided apically into several arms which may be apically united or free; gleba borne on the interior, exterior of or between the arms.

III. Family CLAUSTULACEAE: Receptacle sessile; an obovate or spherical, apparently indehiscent hollow sphere; gleba lining the inner surface.

There would appear to be twenty genera in the Order, containing in all some sixty species; but the number is uncertain owing to differences of opinion held by different workers as to the generic and specific value of many characters.

Family I. PHALLACEAE.

Peridium of three layers, obovate or subglobose, at first submerged, becoming superficial, or almost so; rupturing from the apex downwards to form several lobes, exposing the receptacle and persisting as a volva supporting this structure: gelatinous layer continuous, not broken into plates by intermediate tissue. Receptacle completely free within the volva; stipitate; cylindrical or fusoid, stem hollow, of one or several layers of chambers; bearing the gleba on its modified upper surface, or upon a campanulate pileus attached to its apex. Indusium present in *Dictyophora* and *Clautravia*. Basidia bearing 4-8, sessile, elliptical, smooth spores.

The family contains eight genera, which may be recognized by the following characters:

Key to the Genera.

Gleba borne directly upon the apical portion of the receptacle.
  Gleba covering the apical portion of the receptacle .... 1. *Mutinus*
  Gleba forming a collar-like constriction below the inflated apex of the receptacle .... *(2. *Staheliomyces*)
Gleba covering a net-like pileus loosely attached to the apical portion of the receptacle .... (3. *Floccomutinus*)
Gleba borne on a campanulate pileus.
  Indusium absent or rudimentary only.
    Pileus formed of radiate plates .... (4. *Aporophallus*)
    Pileus formed of lamellate plates .... (5. *Itajahya*)
    Pileus even; exteriorly rugulose, papillate or reticulate .... 6. *Ithyphallus*
  Indusium present and well developed.
    Pileus strongly convoluted .... (7. *Clautravia*)
    Pileus reticulate .... 8. *Dictyophora*

Of these, only *Mutinus*, *Ithyphallus* and *Dictyophora* are known to occur in Australia; and none has been recorded from New Zealand. Of the genera placed under the Phallaceae, *Staheliomyces* (Fischer, 1921) has been found in British Guiana and Surinam (Malay Archipelago); *Floccomutinus* is confined to West Africa; *Aporophallus* is confined to Brazil; *Itajahya* is not uncommon in South America; and *Clautravia* has a distribution through Java, Ceylon, East Indies and probably New Guinea. *Aporophallus* and *Itajahya* resemble *Ithyphallus*, and

* Genera not occurring in Australia are in brackets.

Clautravia resembles *Dictyophora*, but these are separated principally on account of the different structure of the pileus.

Development.

The development of species of the genera *Mutinus*, *Ithyphallus* and *Dictyophora* has been investigated by Burt (1896, with *Mutinus caninus*), Fischer (1886; 1890, with *Ithyphallus impudicus*), and Atkinson (1911, with *I. impudicus*, *I. Ravenelii* and *Dictyophora duplicata*); and from their accounts the following particulars have been derived.

The primordium of the fructification arises as a terminal inflation on the end of the rhizomorph. Each is seen to consist of a cortical layer of loosely-woven hyphae enclosing a central medullary layer of hyphae arranged more or less parallel with the long axis of the primordium. The hyphae of this central tissue are expanded apically into a sheaf-like head, and at a very early stage exhibit between them a quantity of gelatinized tissue. The cortical layer at maturity becomes the outer layer of the peridium, and the medullary layer gives rise to all other tissues. The primordium at this stage is shown in section in fig. 1, Plate 1.

Gelatinization of the hyphae of the upper portion of the medullary layer follows, and this progresses centrifugally and downward until a campanulate gelatinous tissue (which is thicker above) is produced, which later becomes the gelatinous layer of the peridium (Plate i, fig. 2, *f*). While this tissue is developing, and soon after its development commences, the fundaments of the other tissues begin to appear. Thus the fundament of the stem of the receptacle becomes noticeable first as a delicate columnar structure (Plate i, fig. 2, *a*), its apex extending nearly to the apex of the dome of tissue enclosed within the gelatinous layer of the peridium. The tissue lying next this later forms the inner wall of the peridium. And between it and the fundament of the stem of the receptacle lies the fundament of the gleba. Within this again is another bell-shaped zone, the fundament of the pileus (in *Ithyphallus* and *Dictyophora*, but not in *Mutinus*). Thus about the time the stem of the receptacle becomes differentiated, commences likewise development of the inner wall of the peridium (or rather the zone at which separation takes place, Plate i, fig. 2, *d*), the gleba and the pileus (Plate i, fig. 2, *p*).

The fundament of the gleba now produces upon its inner face a palisade layer of slender clavate cells. By growth of the tissues in this region, numerous plates develop which fold and branch freely as they extend inwards towards the receptacle; until finally the whole of the primordial tissue (save a narrow zone contiguous to the receptacle) becomes converted into the tramal plates of the gleba (Plate i, fig. 3, *g*). These plates become more freely branched and shortly form a labyrinth of plates and cavities. On the surfaces lining the cavities basidia appear, and profuse spore production then takes place. During this period, formation of the stem of the receptacle is progressing. Opinions differ as to the manner in which it is formed. Fischer (1890) considered the wall was formed from the outer portion of the medullary strand (which passes up from the rhizomorph as a slender cylinder and expands apically to form the capitate head of the medullary layer); whereas Burt (1896) believed that this strand played no part in the formation of the receptacle, but that all tissues (save the outer layer of the peridium) are derived from the capitate apex of the medulla. Atkinson (1911) was inclined to support Burt's interpretation.

The wall of the receptacle finally becomes pseudoparenchymatous and strongly folded. The central portion is filled with undifferentiated tissue which later becomes gelatinized and ultimately disappears (being utilized in giving the necessary turgescence to the expanding receptacle) to leave the mature and expanded receptacle hollow.

In *Mutinus* the apex of the receptacle becomes modified, according to the species, appearing as a smooth surface, covered with loosely arranged pseudoparenchymatous cells, or of digitate processes. As the tissue of the gleba continues to develop, the tramal plates press against the remaining primordial (undifferentiated) tissue lying between it and the receptacle apex, causing the gleba to become adnate at maturity. The stem of the receptacle during this later stage of development is only slightly compressed where in contact with the gleba, but much convoluted basally. Finally the tramal plates become gelatinized and the gleba becomes attached to the apical portion of the receptacle as a viscid mass. Owing to increased turgidity of the cells of the receptacle (partly due to enlargement of the whole through growth, but principally due to the pressure exerted through increased turgescence owing to absorption of the gelatinous matrix of the central core of the receptacle), pressure is exerted upon the apex of the peridium. This ruptures and remains as a cup (the volva) at the base of the receptacle. The convolutions in the latter flatten out, causing the receptacle to elongate, when it appears as a mature plant, the apex coated with the viscid, now fetid, gleba, the base held loosely within the volva.

In *Ithyphallus* and *Dictyophora*, however, development proceeds further, for the gleba, instead of being carried on the apex of the stem of the receptacle, is borne upon a well-developed pileus. This additional structure is formed in the primordial tissue situated between the fundaments of the gleba and receptacle, being separated from the latter by undifferentiated tissue. As development progresses it becomes converted to pseudoparenchyma and assumes a form characteristic of the species. The pileus is bell-shaped, and occupies a considerable portion of the area of the unexpanded plant, extending from near the apex (within the gelatinous layer of the peridium) to the base. Throughout its whole surface it is in intimate contact with the gleba, and serves effectively to prevent the gleba from coming in contact with the stem of the receptacle, which until rupture of the peridium is compressed within the pileus. The section (Plate I, fig. 4) of *Ithyphallus impudicus* shows the manner in which the gleba comes in contact with the reticulated pileus of this species. Between pileus and receptacle persists a residuum of fundamental tissue, to form at maturity the evanescent veil (and basal "collar") which may be noted in many species immediately following rupture of the peridium.

In *Dictyophora* (and *Clautravia*) there is an additional tissue, the indusium. This develops within the primordial tissue lying between pileus and receptacle, utilizing the residuum which, in *Ithyphallus*, forms the veil. The indusium is composed of chambered pseudoparenchyma of a similar nature to that of the receptacle, and, like the latter, is much convoluted during development, and remains in this condition until the peridium is ruptured, when the folds flatten out, causing it to appear from beneath the pileus as a delicate, pendent, campanulate, latticed tissue.

In *Ithyphallus impudicus*, Atkinson (1911) recorded a rudimentary indusium which had not advanced beyond the condition of a more densely compacted

primordium. This rudiment occupied the position in which the indusium develops in *Dictyophora*, and was composed of the same fundamental tissue which, undifferentiated, gives rise to the veil of *Ithyphallus*; differentiated, produces the indusium of *Dictyophora*.

1. Mutinus Fries.

Syst. Veg. Scand., ii, 1849, p. 434.—*Phallus*§*Cynophallus* Fr., *Syst. Myc.*, ii, 1822, p. 284.—*Cynophallus* (Fr.) Cda., *Icon. Fung.*, vi, 1854, p. 19.—*Corynites* Berk. et Curt., *Trans. Linn. Soc.*, xxi, 1855, p. 149.—*Jansia* Penz., *Ann. Jard. bot. Buit.*, xvi, 1899, p. 139.—*Phallus* Auctt.

Receptacle a hollow, simple, cylindrical or fusiform, coloured stem, closed below, pervious or impervious above; wall chambered, cavities usually opening to the exterior below, to the interior in the glebiferous region. Gleba mucilaginous, olivaceous, fetid, borne upon the apical portion of the receptacle, which may be externally smooth or covered with pseudoparenchymatous pulvinate or digitate processes.

Habitat.—Growing upon the ground, or on decayed wood.

Type Species, Mutinus caninus (Huds. ex Pers.) Fr.

Distribution.—Europe; Asia; North and South America; Africa; India; Ceylon; Java; Australia.

The genus is the most primitive of those in the family, consisting as it does of plants with a receptacle in the form of a simple hollow stem with the apical portion modified to carry the gleba. There would appear to be nine valid species in the genus, the numerous others which have been described being synonyms or forms of these. Of the generic synonyms *Jansia* alone is used by certain recent workers in a valid sense. Fischer (1900, p. 556) reduced it to a subgenus of *Mutinus*, characterized by the hollow digitate processes developed upon the wall of the apical part of the receptacle. Petch (1908, p. 143) has shown that the Ceylon *Mutinus proximus* is intermediate between *M. borneensis* ("Jansia rugosa") and *M. Penzigii* Fisch. ("Jansia elegans"), as it has the blunt anastomosing ridges of the former mixed with the appendages of the latter. It is evident therefore that *Jansia* cannot be maintained.

Mutinus may be divided into three sections upon the nature of the glebiferous region of the receptacle, thus:

I. Section *Glabrosi*: apical portion of the receptacle glabrous, either tuberculate or regularly reticulated with raised bands. (*M. caninus*; *M. curtus*; *M. elegans*; *M. Fleischeri*; *M. xylogenus*.)

II. Section *Granulosi*: apical portion of the receptacle covered with irregular pseudoparenchymatous processes, appearing granular or pseudo-reticulate. (*M. bambusinus*; *M. borneensis*.)

III. Section *Tuberculosi*: apical part of the receptacle covered with digitate processes. (*M. Penzigii*; *M. proximus*.)

Apparently but two species are known to occur with certainty in Australia, the numerous other records being based upon synonyms or misdeterminations of these.

1. Mutinus curtus (Berkeley) Fischer. Plate i, fig. 6.

Sacc., *Syll. Fung.*, vii, 1888, p. 13.—*Phallus curtus* Berk., in Hook. *Lond. Jour. Bot.*, iv, 1845, p. 69.—*Mutinus papuasius* Kalchbr., *Grev.*, iv, 1875, p. 74.—*Phallus* (*Cynophallus*) *papuasius* Kalchbr., *Ber. Nat. Akad. Wiss.*, x, 1880, p. 19.—*P. annulatus* Bailey ex Lloyd, *Phall. Aus.*, 1907, p. 13.—*Jansia annulata* (Bailey)

Lloyd, *Syn. Phall.*, 1909, p. 34.—*Mutinus annulatus* Bailey, *Comp. Cat. Queensland Pl.*, 1910, p. 745.

Peridium subglobose, white, to 15 mm. diameter. Receptacle to 3 cm. tall, 5–8 mm. diameter, hollow, fusiform, white below, pallid-red beneath the gleba, yellowish towards the sterile and pervious apex, finely but obscurely transversely rugulose throughout its length. Gleba sage-green in mass, arranged in an irregular zone around the upper portion of the receptacle, but not on the prominent sterile apex, fetid. Spores smooth, tinted, elliptical, $3 \cdot 5 \times 1 \cdot 8$ μ.

Type locality.—Swan River, Western Australia.

Distribution.—Australia: W. Aust.: Swan River (Berkeley, *l.c.*). Queensland: Rockhampton (as *M. papuasius*, Kalchbr., *l.c.*); Brisbane (as *M. annulatus*, Bailey, *l.c.*). N.S.W.: Mt. Wilson; Kurrajong Heights (Cleland and Cheel, 1915).

Cleland and Cheel (1915) have suggested that *Mutinus curtus* as illustrated by Corda (*Icon. Fung.*, vi, 1854, Pl. 3, f. 47) and *M. papuasius* as illustrated by Kalchbrenner (*l.c.*, 1880, Pl. 3, f. 1) are the same species, and that both figures refer to the species here considered as *M. curtus*. The illustrations show totally different plants, but as Berkeley's original description agrees very closely with the Mt. Wilson plant, it is evident Corda's drawing is largely diagrammatic, and, as Cleland and Cheel have suggested, constructed from an unexpanded plant. According to the same workers, Kalchbrenner's figure, if the greatly elongated stem were considerably shortened, resembles closely the two collections they recorded. From the particulars they have given, there can be little doubt but that such is the case, and that *M. papuasius* is a synonym of *M. curtus*. As an additional synonym I would add *Mutinus annulatus*, as it appears from the illustration to possess the same transversely-rugose receptacle, although the attenuate apex appears to be considerably exaggerated, and to suggest it to be a plant Fischer named as *M. boninensis* (which in turn is a synonym of *M. bambusinus*).

The minute size and transversely-rugose nature of the receptacle appear to characterize the species, and to separate it from the four other species which occur in the tropic or subtropic regions.

2. Mutinus borneensis Cesati. Plate ii, fig. 7.

Atti. Acc. d. Sci. Napoli, viii, 1879, Pl. 1, fig. 1.—*Phallus Watsoni* Berk., *Journ. Linn. Soc.*, Bot., xviii, 1881, p. 387.—*Mutinus? Watsoni* (Berk.) Fisch., in Sacc. *Syll. Fung.*, vii, 1888, p. 13.—*Floccomutinus nymenianus* P. Henn., *Monsunia*, i, 1899, p. 22.—*Jansia nymeniana* (P. Henn.) Penz., *Ann. Jard. bot. Buit.*, xvi, 1899, p. 139.—*J. rugosa* Penz., *l.c.*, p. 142.—*J. truncata* McAlp., in Lloyd's *Myc. Notes*, 1910, p. 484.

Peridium white, obovate, to $2 \times 1 \cdot 5$ cm., splitting into 3–4 blunt and irregular lobes. Receptacle to 8×3 cm., fusiform, hollow, acuminate above and below, pervious at the apex, white at the base, becoming salmon-pink at the glebiferous region. Gleba borne on an irregular, fragile, raised network of variable meshes, olivaceous, fetid. Spores elliptical, hyaline, smooth, $3\text{–}3 \cdot 5 \times 1\text{–}1 \cdot 8$ μ.

Type locality.—Matang, Borneo.

Distribution.—East Indies. Australia: Queensland: Burnett River (Berkeley, *l.c.*, as *Phallus Watsoni*); Victoria: Melbourne (McAlpine, *l.c.*, as *Jansia truncata*); N.S.W.: Rookwood, Sydney, Mosman Bay (Cleland and Cheel, 1915, p. 203), Bradley's Head, North Dorrigo (Cleland and Cheel, 1923, p. 72).

This is separated from the preceding species by the larger size, and especially by the delicate structure bearing the gleba, which appears in the form of a raised

network corresponding to the polygonal depressions of the chambers of the receptacle.

Lloyd (*Myc. Notes*, 1923, p. 1215) examined the type specimen and drawing of *M. borneensis* in the herbarium of Cesati and found it to be identical with *Jansia rugosa* Penz. Fischer, as a result of examination of the type at Berlin, considered *Floccomutinus nymenianus* was also identical with *J. rugosa*. I have examined part of the type collection of *Jansia truncata*, and agree with Lloyd (*Myc. Notes*, 1910, p. 485) that it, too, is the same as *J. rugosa*, differing only in the somewhat larger size. And the description of *Phallus Watsoni* given by Berkeley shows it to belong to the same species. From this it becomes evident that the prior name for the species is *M. borneensis*, and that *Phallus Watsoni*, *Flocoomutinus nymenianus*, *Jansia rugosa* and *J. truncata* are synonyms.

In a recent paper Petch (1926) described the microscopic structure of the pseudoparenchymatous processes upon the glebiferous portion of the receptacle of *M. bambusinus*. From this it would appear that *M. borneensis* in this particular closely resembles *M. bambusinus*, differing in that these processes are more strongly developed and arranged in an irregular network. His account and illustrations show *M. bambusinus* to differ in this and in the pervious chambers of the non-glebiferous portion of the receptacle (closed and polygonal in *M. borneensis*), and for this reason I consider *M. borneensis* a valid species. Petch has shown that *M. boninensis* and *M. Muelleri* are synonyms of *M. bambusinus*; that the apex may or may not be sterile, pervious or truncate, and that plants vary considerably in size. The odour of this species has been described by McAlpine (*l.c.*) as resembling scorched linen; by Cleland and Cheel (1923, p. 72) as musty but not fetid.

2. Ithyphallus (Fries) Fischer.

Ann. Jard. bot. Buit., vi, 1886, p. 4.—*Hymenophallus* Nees, *Syst. Pilz. u. Schw.*, 1817, p. 251.—*Phallus*§*Ithyphallus* Fr., *Syst. Myc.*, ii, 1822, p. 283.—*Phallus* §*Leiophallus* Fr., *l.c.*, p. 284.—*Dictyophallus* Cda., *Icon. Fung.*, vi, 1854, p. 19.—*Kirchbaumia* Schulzer, *Verh. k. Wien. Zool.-Bot. Gesell.*, xvi, 1866, p. 798.—*Omphalophallus* Kalchbr., *Flora*, xlvi, 1883, p. 95.—*Phallus* Auctt.

Receptacle a hollow, cylindrical or fusoid stem bearing an apically attached campanulate pileus, which may be smooth, rugulose or reticulate; apex usually pervious; indusium absent, but an evanescent veil often present. Gleba olivaceous, mucilaginous, usually fetid, covering the exterior of the pileus.

Type species, *Ithyphallus impudicus* (L. ex Fr.) Fisch.

Distribution.—Europe; Asia; North and South America; Africa; Australia; East and West Indies.

The presence of an additional structure, the pileus, borne apically on the receptacle, separates this genus from *Mutinus*; and from *Dictyophora* it is separated by the absence of an indusium. In several species is present a veil which has by many workers been confused with the indusium. But, as Atkinson (1911) has shown, the veil consists of a membranous, delicate layer of fundamental tissue lying between pileus and apex of the receptacle in unexpanded plants. As the stem of the receptacle elongates this is torn and fragments are left as a veil on the surface of the stem of the receptacle and the inner surface of the pileus, and as a collar at the base of the receptacle. It is seen as a rule only in freshly expanded plants, for it quickly disappears after exposure. It

is evident, therefore, that the veil is merely undifferentiated tissue, structurally different from the pseudoparenchymatous indusium of *Dictyophora*.

There are about eight valid species in the genus, which may be separated into two sections on the surface markings of the pileus:

I. Section *Reticulati*: pileus with raised reticulations.
   (*I. costatus*; *I. impudicus*; *I. paucinervis*; *I. tenuis*.)
II. Section *Rugulosi*: pileus finely rugulose or smooth.
   (*I. glutinolens*; *I. Ravenelii*; *I. rugulosus*; *I. rubicundus*.)

Ithyphallus impudicus is the common European species, and extends to North America (as *I. imperialis*). It has a white receptacle and pileus. (*I. imperialis* is a colour form with a pink volva and base of the receptacle.) *I. costatus* is a Javan form with more strongly developed reticulations; and *I. paucinervis* a form from Surinam (Malay Archipelago) with scantily developed irregular reticulations. *I. tenuis* is a distinct tropic species, found in Java, Ceylon and Japan, characterized by its small size, yellow pileus and receptacle, and reticulated pileus. The rugulose section contains three well defined species. *I. Ravenelii* possesses a white receptacle and is confined to North America; *I. rubicundus* has a red receptacle and pileus and is common in India, southern North America, West Indies, Africa and Australia; and *I. glutinolens*, characterized by the depressed globose shape of the pileus, is confined to Brazil. *I. rugulosus*, confined to Japan, is a form of *I. rubicundus* differing only in the colour of the pileus. The many others which have been described are but synonyms of these, or of species of *Dictyophora*.

The genus is represented in Australia by the following solitary species, though many others have been recorded.

1. ITHYPHALLUS RUBICUNDUS (Bosc.) Fischer. Plate ii, fig. 8.

Jahrb. bot. Gart. u. Mus. Berlin, iv, 1886, p. 50.—*Satyrus rubicundus* Bosc., *Mag. Ges. nat. Freunde Berlin*, v, 1811, p. 86.—*Phallus*§*Leiophallus rubicundus* Fr., *Syst. Myc.*, ii, 1822, p. 284.—*Phallus canariensis* Mont., *Phyto. Canariensis*, 1840, p. 84.—*P. aurantiacus* Mont., *Ann. Sci. Nat.*, ser. 2, xvi, 1841, p. 277.—*Dictyophallus aurantiacus* Cda., *Icon. Fung.*, vi, 1854, p. 19.—*Phallus aurantiacus* var. *discolor* Kalch., *Grev.*, ix, 1880, p. 2.—*Cynophallus Cayleyi* Berk., ex F.v.M., *Fragm. Phyto.*, xi, 1880, p. 119.—*Omphalophallus Muellerianus* Kalch., *Flora*, xlvi, 1883, p. 95.—*Phallus libidinosus* Cayley ex Cke., *Grev.*, xi, 1883, p. 57.—*Omphalophallus retusus* Kalch., *Ungar. Akad. Wiss. Budapest*, xiii, 1884, p. 6.—*Ithyphallus retusus* (Kalch.) Fisch., *Jahrb. bot. Gart. u. Mus. Berlin*, iv, 1886, p. 49.—*I. aurantiacus* (Mont.) Fisch., *l.c.*, p. 51.—*I. ? canariensis* (Mont.) Fisch., in Sacc. *Syll. Fung.*, vii, 1888, p. 10.—*I. retusus* (Kalch.) Fisch., *l.c.*, p. 11.—*Phallus novae-hollandiae* Cda. ex Fisch., *Denks. Schweiz. nat. Gesell.*, xxxii, 1890, p. 88.—*Mutinus ? discolor* (Kalch.) Fisch., *l.c.*, p. 93.—*Omphalophallus calvescens* Kalch. ex Fisch., *Denks. Schweiz. nat. Gesell.*, xxxiii, 1893, p. 34.—*Ithyphallus Muellerianus* (Kalch.) Fisch., *l.c.*, p. 34.—*Phallus celebicus* P. Henn., *Monsunia*, i, 1899, p. 21.—*P. sanguineus* P. Henn., Engl. *Bot. Jahrb.*, xxx, 1901, p. 57.—*Ithyphallus celebicus* (P. Henn.) Sacc. et Syd., in Sacc. *Syll. Fung.*, xvi, 1902, p. 225.—*I. sanguineus* (P. Henn.) Sacc., *Syll. Fung.*, xvii, 1905, p. 212.—*I. coralloides* Cobb, *Exp. Stn. Hawaii* Bull. 5, 1906, p. 208.—*Phallus discolor* (Kalch.) Lloyd, *Phall. Aus.*, 1907, p. 10.—*P. gracilis* (Fisch.) Lloyd, *Syn. Phall.*, 1909, p. 14.—*Ithyphallus discolor* (Kalch.) Sacc. et Trav., in Sacc. *Syll. Fung.*, xix, 1910, p. 987.—*I. atrominiatus* Bailey, *Comp. Cat. Queensland Pl.*, 1910, p. 746.—*I. operculatus* Bailey, *l.c.*

Peridium ovate or subglobose, to 3 cm. diameter, solitary or in small groups of 2–6. Receptacle variable in size and shape, fusiform or cylindrical, to 18 × 3 cm., scarlet, wall several chambers in thickness; pileus conical, slightly rugulose, scarlet, apex perforate. Gleba covering the exterior of the pileus, mucilaginous, fetid, olivaceous. Spores smooth, elliptical, tinted, 3·5–5 × 1·5–2 μ.

Type locality.—South Carolina, North America.

Distribution.—Southern North America; West Indies; Africa; India; Hawaii; Australia.

Queensland: Burnett District (Herb. Brit. Mus., Fischer, 1893, p. 37); Brisbane (Bailey, *l.c.*, as *I. atrominiatus* and *I. operculatus*); Toowoomba; Darling Downs (Herb. Kew, Fischer, 1893, p. 37).—N.S.W.: Mossgiel (Herb. Berol., Fisch., 1893, p. 35, as *I. Muellerianus*); Illawarra (Kalchbrenner, *l.c.*, as *Omphalophallus Muellerianus*); Mudgee (Herb. Berlin, Fischer, 1890, p. 88 as *I. aurantiacus* f. *gracilis*); Campbelltown; Richmond River; Grafton (Nat. herb., Sydney, Cleland and Cheel, 1915, p. 200).—Victoria: Melbourne; Yarra Yarra.—S. Aust.: Kingston (Cleland, 1924, p. 251, in herb. Cleland).—Tasmania: No locality (herb. Delessert, Fischer, 1890, p. 88).

This species appears to be common in the tropic and subtropic regions. In Australia it has been collected fairly frequently, as the records show, and recorded under *Ithyphallus aurantiacus* f. *gracilis*, *I. Muellerianus*, *I. retusus*, *I. novae-hollandiae*, *I. atrominiatus*, *I. operculatus*, *Mutinus discolor*, *Phallus rubicundus* var. *gracilis* and *P. gracilis*, all of which are synonyms of the same species, for there is no character (other than size) by which one form may be separated from another; and size in a variable species where so many intermediate forms are known, has no specific value. The scarlet colour of the pileus and receptacle, and finely rugulose pileus, characterize the species.

3. Dictyophora Desvaux.

Jour. de Bot., ii, 1809, p. 88.—*Hymenophallus* Nees, *Syst. Pilz. u. Schw.*, 1817, p. 251.—*Phallus*§*Hymenophallus* Fr., *Syst. Myc.*, ii, 1822, p. 282.—*Sophronia* Gaud., *Voy. aut. Monde*, 1826, p. 178.—*Phallus* Auctt.

With the characters of *Ithyphallus* and in addition a definite indusium. This is a campanulate, latticed, pseudoparenchymatous, pendent membrane, apically attached to the apex of the receptacle beneath the pileus, and basally free, extending to a position midway between volva and pileus.

Type species, Dictyophora indusiata (Vent. ex Pers.) Fisch.

Distribution.—Africa; North and South America; East and West Indies; India; Ceylon; China; Cook Islands; Australia.

As has been shown, the indusium characterizes the genus, and is a very different structure from the veil. The function of this distinctive membrane is unknown, but it possibly aids in attracting insects to the plant to assist in spore dispersal.

There would appear to be but four valid species in the genus, the many others described being synonyms of this or *Clautravia*, or at most colour forms. *D. indusiata* apparently has a wide distribution through the tropic and subtropic regions, and is characterized by the white indusium and receptacle, and by the rugulose-reticulate nature of the pileus. *D. duplicata*, confined to North America, closely resembles the preceding (and by many workers is considered to be identical), but is separated by the more definite nature of the reticulations of the pileus. *D. Farlowii*, which is confined to Brazil, differs in the structure of the

indusium and reticulations of the pileus. *D. multicolor* is similar to *D. indusiata* in form, but differs considerably in colour. It has a limited distribution in Australia and Java.

1. DICTYOPHORA INDUSIATA (Vent. ex Pers.) Fischer. Plate ii, fig. 9.

Unter. Phall. Surinam, 1928, p. 28.—*Phallus indusiatus* Vent. ex Pers., *Syn. Meth. Fung.*, 1801, p. 244.—*Dictyophora phalloidea* Desv., *Jour. de Bot.*, ii, 1809, p. 88.—*Hymenophallus indusiatus* (Vent.) Nees, *Syst. Pilz. u. Schw.*, 1817, p. 252.—*Sophronia braziliensis* Gaud., *Voy. aut. Monde*, 1826, p. 178.—*Dictyophora campanulata* Nees ex Lev., *Mem. Soc. Linn. Paris*, v, 1827, p. 499.—*D. speciosa* Meyen, *Nov. Acad.*, xix, 1843, p. 239.—*D. bicampanulata* Mont., *Ann. Sci. Nat.* ser. 3, x, 1848, p. 120.—*D. radicata* Mont., *Ann. Sci. Nat.*, ser. 3, iii, 1855, p. 137.—*Phallus speciosus* Schlecht., *Linnaea*, xxxi, 1862, p. 121.—*P. braziliensis* Schlecht., *l.c.*, p. 124.—*P. tahitiensis* Schlecht., *l.c.*, p. 126.—*P. radicatus* (Mont.) Schlecht., *l.c.*, p. 129.—*Dictyophora nana* Berk. ex Cke., *Grev.*, xi, 1882, p. 39.—*Phallus collaris* Cragin, *Bull. Washborn Coll.*, i, 1885, p. 33.—*Dictyophora braziliensis* (Schlecht.) Fisch., *Jahrb. bot. Gart. u. Mus. Berlin*, iv, 1886, p. 32.—*D. tahitiensis* (Schlecht.) Fisch., *l.c.*, p. 37.—*Hymenophallus alboindusiatus* Loth. ex Fisch., in Sacc. *Syll. Fung.*, vii, 1888, p. 469.—*Phallus diplopora* Mont. ex Fisch., *Denks. Schweiz. nat. Gesell.*, xxxii, 1890, p. 81.—*Dictyophora callichroa* A. Moell., *Braz. Pilz.*, 1899, p. 129.—*D. Lilloi* Speg., *An. Mus. Nac. Buenos Aires*, xvi, 1906, p. 30.—*Phallus callichrous* (A. Moell.) Lloyd, *Phall. Aus.*, 1907, p. 6.—*P. rochesterensis* Lloyd, *Syn. Phall.*, 1909, p. 20.—*P. Moelleri* Lloyd, *l.c.*

Peridium ovate or subglobose, to 4 cm. diameter, white. Receptacle fusiform or cylindrical, to 20 × 3·5 cm., white, hollow; pileus campanulate, dingy-yellow when the gleba is removed, reticulate-rugulose, the reticulations being even and with rounded edges, apex perforate, collar raised and distinct. Indusium coarsely net-like, white, pendent, campanulate, apertures large, bars elliptical. Gleba olivaceous, spread between the reticulations over the pileus, fetid, mucilaginous. Spores elliptical, smooth, tinted, 3·5–4·5 × 1·5–2 μ.

Type locality.—Dutch Guiana.

Distribution.—Africa; North and South America; Asia; East and West Indies; India; Ceylon; Australia.

Queensland: Daintree River (Fischer, 1890, p. 81); Brisbane (Herb. Kew, Fischer, 1893, p. 31); Endeavour River (Herb. Kew, Fischer, 1893, p. 31).—N.S.W.: Neutral Bay; Booyong (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 200).—Cook Islands: Samoa (Lloyd, 1909, p. 18).

This species varies considerably in size, structure of the indusium, and especially in the sculpturing of the pileus. Shortly after a plant has emerged from the peridium the pileus appears rugulose, but as it ages the pileus becomes more clearly reticulated, the reticulations becoming thinner and more sharply defined.

2. DICTYOPHORA MULTICOLOR Berkeley and Broome. Plate ii, fig. 10.

Trans. Linn. Soc. Lond., ser. 2, ii, 1883, p. 66.—*Phallus quadricolor* Berk. et Br., *l.c.*—*P. calyptratus* B. et Br., *l.c.*—*Ithyphallus quadricolor* (B. et Br.) Fisch., *Jahrb. bot. Gart. u. Mus. Berlin*, iv, 1886, p. 45.—*I. calyptratus* (B. et Br.) Fisch., *l.c.*, p. 46.—*Phallus multicolor* (B. et Br.) Lloyd, *Phall. Aus.*, 1907, p. 6.

Receptacle fusiform, to 16 × 3 cm., white below, pink above, hollow, of three layers of fine chambers; pileus conical, irregularly reticulate, orange, pervious,

thin and tough. Indusium pendent, to 4 cm. below the pileus, salmon-pink, with fine meshes. Gleba olive-brown, spread between the reticulations of the pileus. Spores tinted, elliptical, smooth, $3{\cdot}5 \times 1{\cdot}8\ \mu$.

Type locality.—Brisbane, Queensland.

Distribution.—Australia; Java.

Queensland: Brisbane (Herb. Brit. Mus., Fisch., 1893, p. 33).—N.S.W.: Ballina (Cleland and Cheel, 1915, p. 200); National Park (Cleland and Cheel, 1923, p. 72).

This is a strongly marked colour form of *D. indusiata*. The colour is not always constant, for in the type collection the receptacle was stated to be pallid-yellow (or cream coloured), the indusium bright lemon-yellow and the pileus orange. The type of "*Phallus quadricolor*" was stated to possess a lemon-yellow stipe, orange pileus, white volva and purple mycelium. Cleland and Cheel (1923, p. 72) have described a specimen from National Park (N.S.W.) in which the receptacle was white below, shading from orange to pink above, pileus orange, indusium salmon-pink, and volva tinted lilac. As *D. rosea* (Ces.) Fisch. (Fisch., 1886, p. 35), which was described from Borneo, possessed a pink indusium it is possible it may be the same species; if so this name has priority, the species being described in 1879 (*Hymenophallus roseus* Ces. *Atti Reale Acc. sci. nat. Napoli*, viii, p. 12). But as it is not possible from Cesati's description to determine to what plant he was referring, and as no type exists, I prefer to use a name which is associated with a known plant.

D. multicolor, *Phallus quadricolor* and *P. calyptratus* were based on specimens collected near Brisbane by Bailey, now in the herbarium of the British Museum (South Kensington). All three possess a reticulated pileus, which suggests that they are collections of the same species. And this belief is strengthened by the fact that the two former agree in all particulars (even to the unusual colouring) save that "*Phallus quadricolor*" has no indusium, and *P. calyptratus* lacks an indusium and possesses a portion of the volva accidentally attached to the apex of the pileus (Lloyd, 1909, p. 22, stated that this was a mass of dried gleba). As all three possess the reticulated pileus and colouring of no other known species, it is evident all are collections of the same species (particularly as they were taken from the same locality), the absence of an indusium being accounted for by loss, since this membrane is delicate and readily detached.

Doubtful and Excluded Species.

a. Dictyophora merulina Berk.—This was recorded in error from Australia by Cooke (1892, p. 212), the plant he has illustrated being *D. indusiata*, collected at Brisbane by F. M. Bailey, and the one which Lloyd (1907, p. 6) named *Phallus rochesterensis*.

b. Ithyphallus impudicus (L. ex Fr.) Fisch.—At Kew is a specimen labelled *I. impudicus*, collected by Bailey from Fringiburra Creek, Queensland. As it possesses a white receptacle and reticulated pileus, and as no other specimen has been found in this region, it is probable that this is a specimen of *D. indusiata* which had lost its indusium.

c. Phallus vitellinus Muell., *Phyt. Aust.*, 1880, p. 122.—This was listed, but not described, among a collection of fungi recorded by von Mueller. Consequently as it is a *nomen nudum*, it should be deleted from our records. Lloyd (1907, p. 8) suggested it was a synonym of *I. rubicundus*.

Acknowledgements.

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EXPLANATION OF PLATES I-II.

Plate I.

1.—Development of *Ithyphallus impudicus*. Young plant shortly after commencement of development. Commencement of gelatinization of tissue to form the middle layer of the peridium (mesoperidium); the dark area is the fundament of the fruit body. × 17·5. (After Atkinson, 1911.)

2.—Older stage of the same species. *a*, rudiment of the stem of the receptacle; *p*, of the pileus; *d*, the endoperidium; *f*, gelatinous layer of the peridium (mesoperidium); *x*, exoperidium. × 7. (After Atkinson, 1911.)

3.—Later stage showing development of the gleba, *g*; pileus, *p*; and stem, *a*. × 7. (After Atkinson, 1911.)

4.—Plant shortly before the rupture of the peridium. *a*, strongly convoluted stem of the receptacle; *b*, fundamental tissue lying between stem and pileus which gives rise to the veil (the dark line marked *i* is the rudimentary indusium of this species); *p*, reticulated pileus; *g*, chambered gleba before deliquescence; *d*, endoperidium. × 7. (After Atkinson, 1911.)

5.—Development of *Dictyophora duplicata.* Plant shortly before the rupture of the peridium. *a*, strongly convoluted stem of the receptacle; *b*, fundamental tissue which remains as the "collar" at the base of the stem; *i*, convoluted indusium; *p*, pileus; *g*, gleba; *d*, endoperidium; *f*, gelatinous mesoperidium. × 7. (After Atkinson, 1911.)

Plate II.

6.—*Mutinus curtus.* × 0·7. Photograph from a water-colour by Miss Phyllis Clarke.

7.—*Mutinus borneensis.* × $\frac{3}{8}$. (After Cleland and Cheel, 1923.)

8.—*Ithyphallus rubicundus.* × $\frac{1}{5}$. (Photograph by Long, after Lloyd, 1909.)

9.—*Dictyophora indusiata.* × $\frac{1}{3}$. (After Lloyd, 1909.)

10.—*Dictyophora multicolor.* × $\frac{1}{2}$. (After Cleland and Cheel, 1923.)

PETROLOGY OF THE HARTLEY DISTRICT. I.

THE PLUTONIC AND ASSOCIATED ROCKS.

By GERMAINE A. JOPLIN, B.Sc.
Deas-Thomson Scholar and Science Research Scholar of the University of Sydney.

(Seven Text-figures.)

[Read 25th March, 1931.]

INTRODUCTION AND PREVIOUS LITERATURE.

The area examined lies in the Cox Valley in the neighbourhood of Hartley and Little Hartley. It is situated some 70 miles to the west of Sydney, and its furthest westerly limit is about 7 miles west-north-west of Mount Victoria.

A small part only of the Kanimbla bathylith is exposed within this area, so the consideration of the Hartley outcrops alone must necessarily be somewhat incomplete, and great caution must be exercised in coming to any very definite conclusions regarding the intrusion as a whole.

Little previous work has been done on this part of the bathylith, the most important and helpful being a geological sketch map made by Messrs. Ball, Curran and Rienits (1898).

Various isolated parts of the intrusion have received attention in connection with the economic minerals, which are associated with the igneous and metamorphic rocks along their contacts.

In his report on the molybdenite deposits at Yetholme, E. C. Andrews (1916, 1917) gives some account of the igneous rocks, and Jones (1924) refers to the granites at Mount Werong in connection with the silver-lead deposits. W. J. Clunies Ross (1894) records a porphyritic granite, a biotite-granite and a quartz-mica-diorite from Bathurst, but reference will be made to these later. W. R. Browne (1929) reports that aplites and pegmatites, porphyritic biotite-granites, hornblende-biotite-granite, quartz-monzonite, granodiorite, quartz-mica-diorite and more basic types have been recorded from various parts of the mass. No systematic petrological investigations, however, appear to have been undertaken.

General Geology.

A. Sedimentary Series.

The sedimentary series consists of altered and tilted Upper Devonian rocks, and unaltered horizontally bedded Permo-Carboniferous and Triassic strata, with occasional patches of alluvium along the creeks. The plutonic rocks are intrusive into the Devonian Series, and are overlain by an Upper Marine conglomerate, which often contains pebbles of the plutonic rock.

The Devonian strata include arenaceous, argillaceous and calcareous types, all of which show contact metamorphism.

A series of Upper Coal Measure Beds overlie the Upper Marine conglomerate but, owing to extensive denudation, these outcrop only to a limited extent—notably in Hartley Vale and on the Victoria Pass. A small outlier of chert occurs on Mr. Cripps' property in the north-east corner of Portion 169, Parish of Hartley.

Triassic sediments belonging to the Narrabeen and Hawkesbury stages cap the higher levels. These form the upper part of the walls of the Cox Valley, and outcrop on a few isolated hills within the valley itself, as on Camel's Back.

Numerous patches of recent alluvium and small bogs occur along the creeks, which are making their way into the entrenched river, and in places clearing of timber has caused gullying and the creeks have begun to cut through their own silts.

B. Igneous Rocks.

Though several types of igneous occurrences are met with in the district, the present work is confined to an examination of the bathylithic rocks, so that several interesting problems can receive but brief mention.

Besides the plutonic rocks, hypabyssal and possibly volcanic types occur, but the relations between these and the bathylith are not as yet known.

Flows (?).—Two outcrops of felsite are met with in the area—a small occurrence on Moyne Farm, and a larger one on Liddleton. Cox's River has cut a deep gorge in the latter.

At Yetholme, quartz-felsites have been found as pre-granite flows (Andrews, 1916) and, as the Liddleton outcrop shows some evidence of having preceded the granite, it is likely that it may represent a Devonian flow.

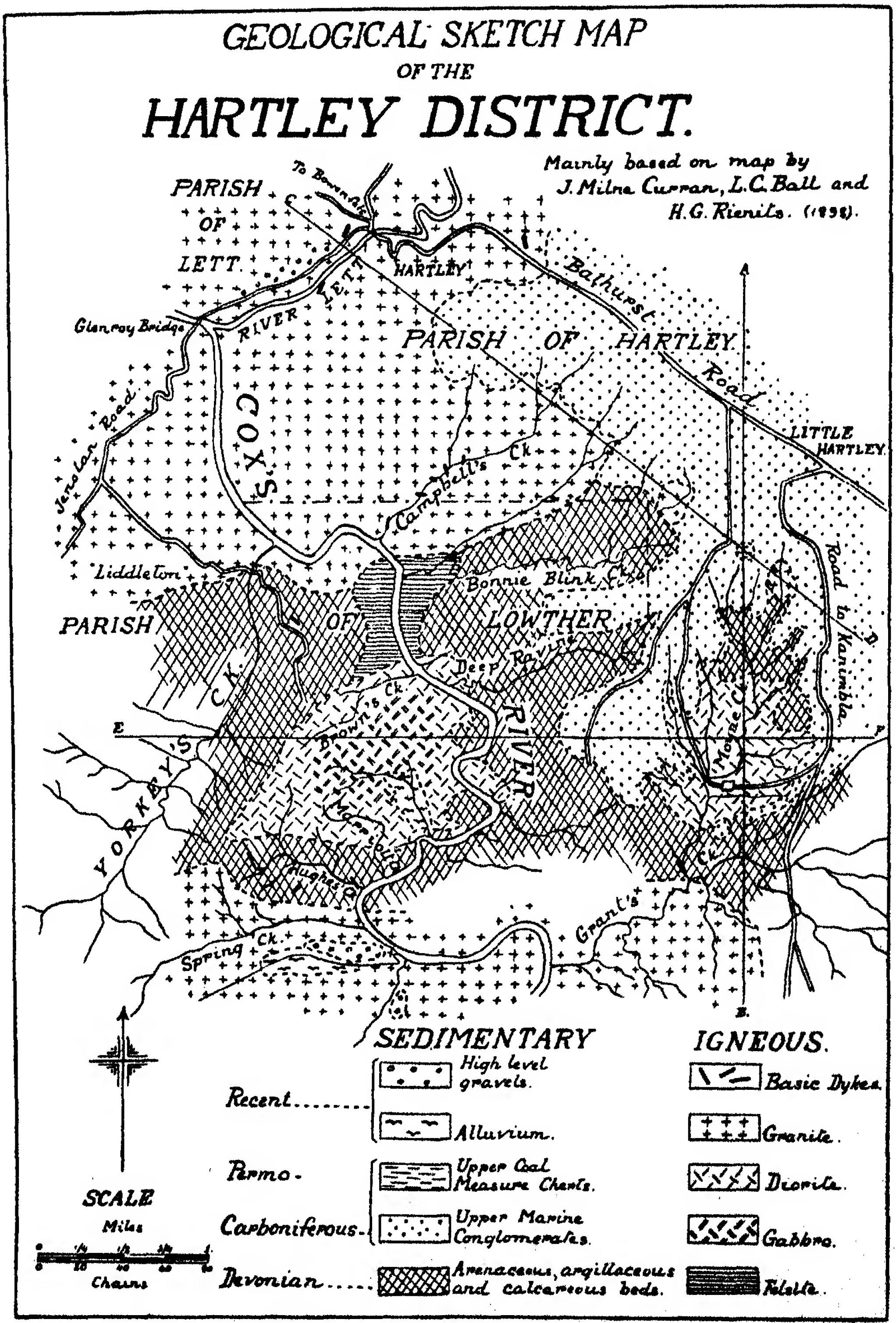
A contact-altered andesite with fluidal fabric occurs in a small outcrop on the ridge above Yorkey's Creek, about 30 chains due west of the felsite on Liddleton.

Sills (?).—Several sill-like outcrops of contact-altered porphyrites, closely resembling the andesite, occur along Hughes Creek, and some of these occur with other altered basic igneous rocks among the Devonian beds on Moyne Creek in Portion 124, Parish of Hartley.

Dykes.—A great many alkaline dykes intrude the plutonic rocks and Devonian sediments. These consist of keratophyres and quartz-keratophyres. Some of the dykes follow prominent lines of jointing in the igneous rock, and appear to be of post-granite origin.

Bathylith.—Since the study of a portion of this intrusion is the subject of the present paper, little need be said about it in this section on the general geology.

The bathylith possibly extends to the west of Hartley beyond Bathurst, and to the south-west as far as Mount Werong, so only a very small part of the great intrusion is represented within the arbitrary limits to which this work has been confined.


GEOLOGICAL SKETCH MAP
OF THE
HARTLEY DISTRICT.
Mainly based on map by
J. Milne Curran, L.C. Ball and
H.G. Rienits. (1898).
PARISH OF LETT
PARISH OF HARTLEY
PARISH OF LOWTHER
HARTLEY
LITTLE HARTLEY
Glenroy Bridge
RIVER LETT
COX'S
Bathurst Road
Jenolan Road
Liddleton
Campbell's Ck
Bonnie Blink Ck
Deep Ravine
RIVER
YORKEY'S CK
Road to Kanimbla
Hughes
Spring Ck
Grant's
SEDIMENTARY
Recent
High level gravels.
Alluvium.
Permo-
Upper Coal Measure Cherts.
Carboniferous.
Upper Marine Conglomerates.
Devonian
Arenaceous, argillaceous and calcareous beds.
IGNEOUS.
Basic Dykes.
Granite.
Diorite.
Gabbro.
Felsite.
SCALE
Miles
Chains

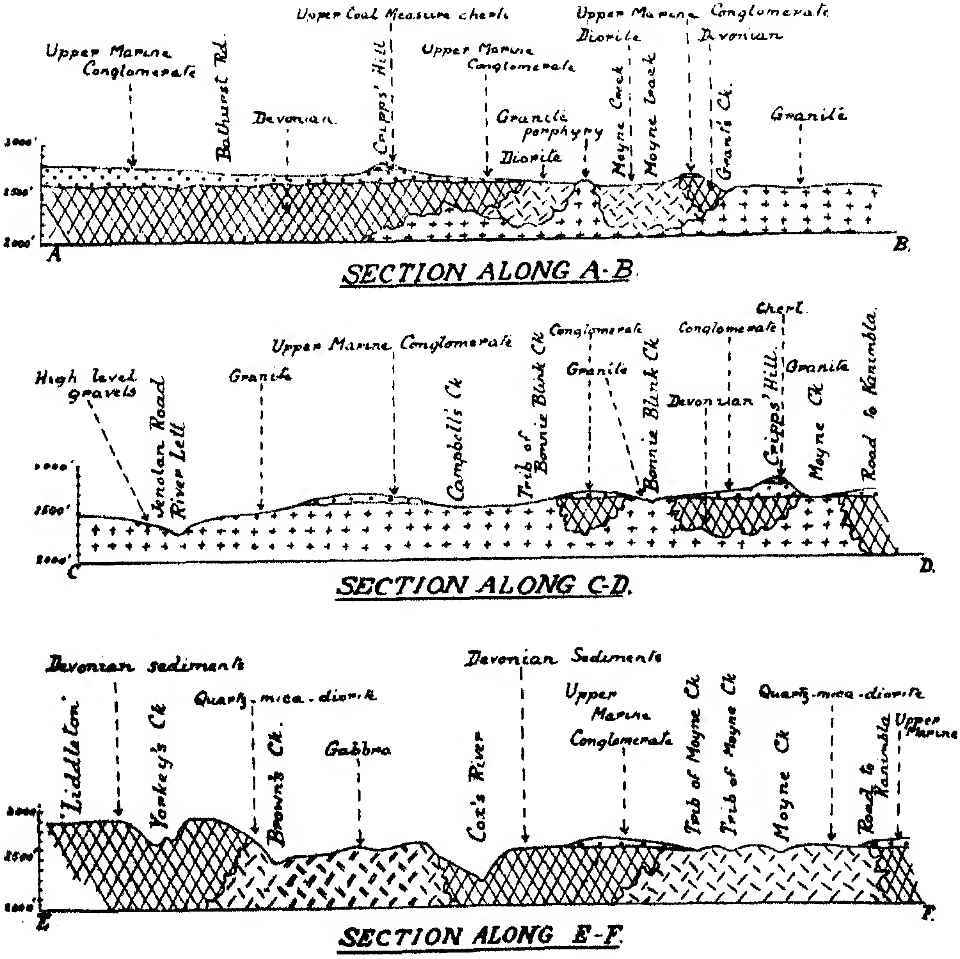
Text-fig. 1.

Bathylithic Types.

A. Field Relations.

The plutonic rocks are intrusive into sediments of Upper Devonian age. Reference to the sketch map (Text-fig. 1) shows granite in the north-west and south-east portions of the area. These two masses are undoubtedly continuous, and represent outcrops of a large bathylith which extends westwards to Bathurst and south-east to Mount Werong.

A large mass of contact-altered Devonian sedimentary rock appears to be included in the granite on Cox's River to the east of Campbell's Creek. This seems to be too large for an inclusion, and may represent a portion of the roof of the bathylith. Furthermore, small inclusions of Devonian rock are very numerous in various parts of the mass, and this also points to the proximity of the roof.



Text-fig. 2.

It will be seen on the sketch map that two masses of basic and intermediate-basic rock occur. The larger of these outcrops on the Cox's River on the properties of Messrs. Chris. Commens and Mitchell. This mass is surrounded by, and is intrusive into, rocks of Devonian age, and in a few instances the beds are seen to dip away from the intrusive rock. The occurrence is probably a stock, and is about one mile by one and a half miles across.

The second smaller intrusion, which also appears to be a stock, is slightly more acid, and occurs on Moyne Farm, the property of Mr. G. Harvey. Though intrusive into Devonian strata, the stock is largely surrounded by overlying beds of Permian age. The intrusion is about one mile in diameter.

The plutonic rocks consist of a series ranging from ultra-basic to acid, and form a complete calcic suite. The series passes from hornblendite and gabbros, through intermediate quartz-mica-diorites, tonalites and granodiorites, into biotite-granites, and there appears to be a gradual transition from one type into another. It will be shown later that the petrography supports this view.

With the exception of most of the aplite dykes and veins, which intersect acid and intermediate types, only one definite junction among the bathylith rocks has been observed. This occurs between a fine and coarse phase of the quartz-mica-diorite, and may be seen in a loose block of the rock on the northern bank of Moyne Creek, just below the farm house.

The biotite-granite, together with a porphyritic phase, is confined to the northern portion of the area. The porphyritic granite outcrops on the Bathurst Road near the Royal Hotel and behind the village of Hartley in the valley of the River Lett. It also occurs on the hillside to the south of the road, and appears to be surrounded by the even-grained acid granite which occurs on the sharp bend of the road just to the east of the Lett Bridge, and on the other side of the road at the junction of the Bathurst and Jenolan Roads.

Several traverses across the granites indicate an increasing basicity away from the margin.

Along the Lett between the bridges the even-grained biotite-granite rapidly passes into a hornblende-biotite-granite, and finally into a rock which stands very close to a granodiorite.

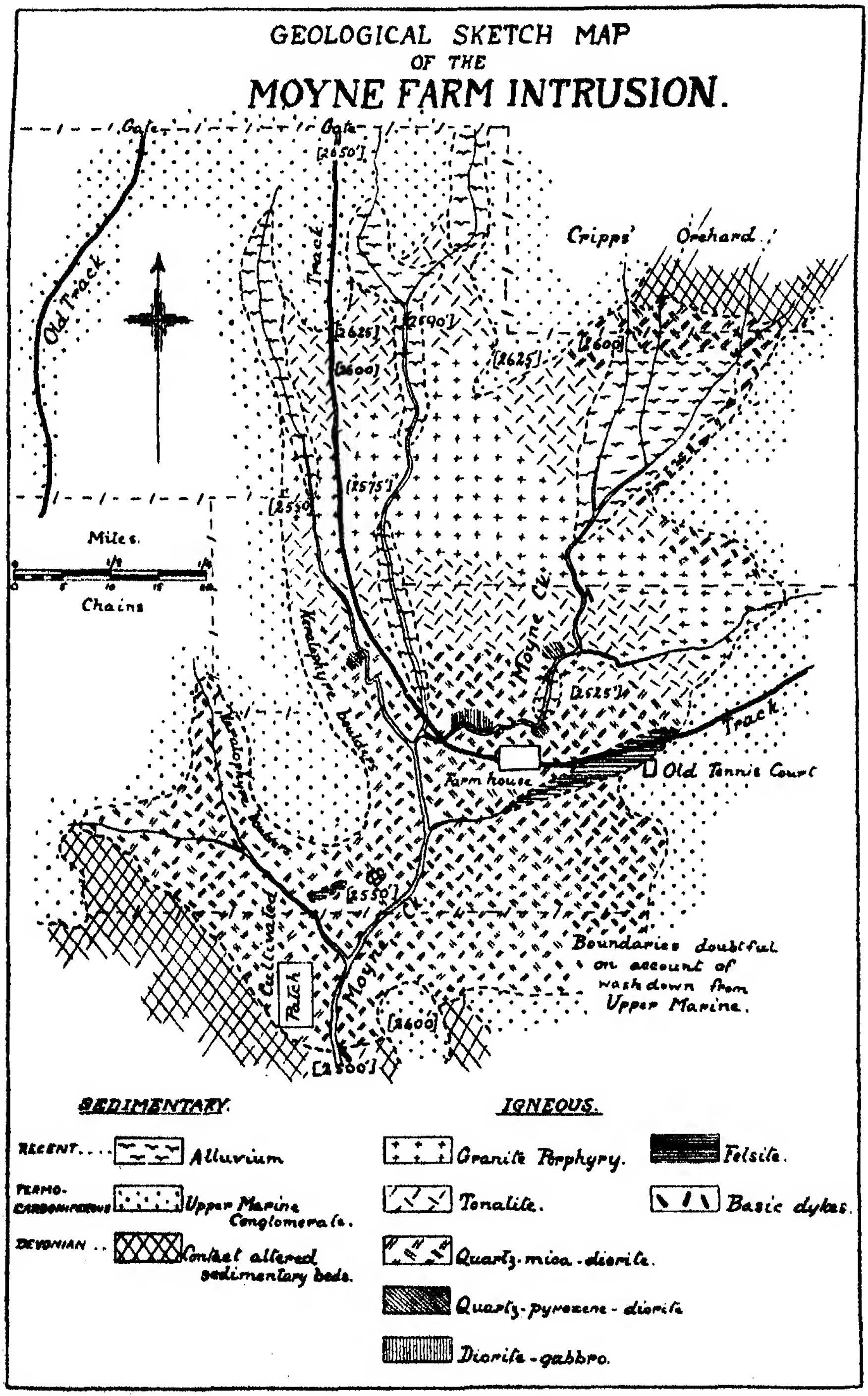
Down Campbell's Creek the same succession is observed, though the most acid phase is not represented in this part of the area.

Another portion of the granite has been examined to the south-east on the properties of Messrs. Hughes, Harvey (Kanimbla Station) and J. S. Commens.

A traverse from the contact of the granite with the Devonian strata down Kanimbla Creek partly reveals the nature of this portion of the intrusion, and a gradual transition from one type into another is apparent here also. A good deal of alluvium and the very deep weathering of the granite, however, prevent the establishment of some of the relations.

On Moyne Creek, apophyses of the granite are fine-grained, and sometimes aplitic, in character. At the junction of this creek with Grant's Creek, a hornblende-biotite-granite occurs, and this rapidly passes into a granodiorite. A few chains above the junction of Kanimbla Creek and Grant's Creek there is a small mass of quartz-mica-diorite, with veins of micropegmatite.

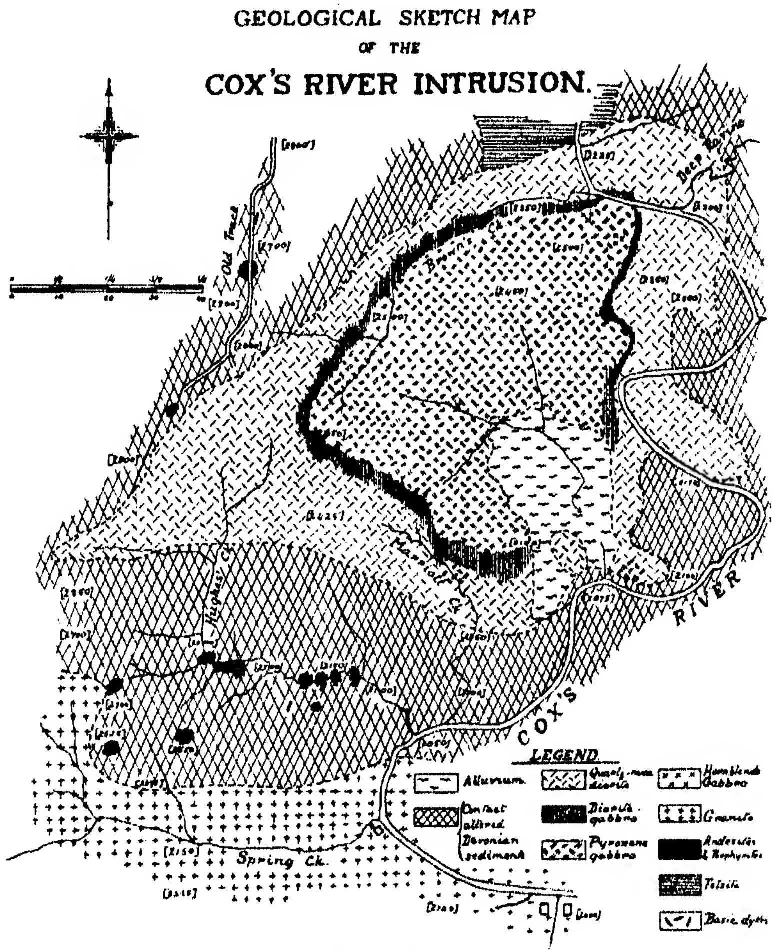
On Kanimbla Station, near the head of the creek, an outcrop of coarse granodiorite, having monzonitic affinities, is met with, but owing to deep weathering


GEOLOGICAL SKETCH MAP
OF THE
MOYNE FARM INTRUSION.
Gate
Gate
[2650']
Old Track
Track
Cripps' Orchard
[2625']
[2590']
[2600']
[2625']
[2600]
[2575']
[2550']
Miles.
Chains
Moyne Ck.
[2525']
Track
Farm house
Old Tennis Court
[2550']
Boundaries doubtful on account of wash down from Upper Marine.
Cultivated
Patch
Moyne Ck.
[2600]
[2500']
SEDIMENTARY.
RECENT
Alluvium
PERMO-CARBONIFEROUS
Upper Marine Conglomerate.
DEVONIAN
Contact altered sedimentary beds.
IGNEOUS.
Granite Porphyry.
Felsite.
Tonalite.
Basic dykes.
Quartz-mica-diorite.
Quartz-pyroxene-diorite
Diorite-gabbro.

Text-fig. 3.

and alluvium, the relations between this rock and the normal granodiorite have not been established.

Several small, apparently isolated, acid masses occur on the properties of Messrs. Harvey (Moyne Farm), Baaner (Bonnie Blink) and Cripps (Cranbrook), and these undoubtedly represent apophyses of the main mass.



Text-fig. 4.

The Cox's River stock consists of an outer margin of quartz-mica-diorite, about 20 chains in width, and often slightly porphyritic in felspar near the contact. It gradually passes into a diorite-gabbro, which seems to represent a reaction-border about a large central mass of gabbro almost a mile in diameter. The gabbro is mainly a pyroxene-bearing variety, but there are scattered patches of hornblende-gabbro and hornblendite throughout the central mass.

The felspar of the gabbros shows clearing, which would suggest a certain amount of contact metamorphism (Harker, 1904; Browne, 1928).

The Moyne Farm stock consists mainly of a quartz-mica-diorite which increases in acidity and passes into a tonalite towards the centre, where it is cut by a dyke or apophysis of granite-porphyry. This latter intrusion must have been contemporaneous, for no sharp contacts between this type and the intruded tonalites have been observed. Sporadically distributed outcrops of quartz-pyroxene-diorite and diorite-gabbro occur among both the quartz-mica-diorite and tonalite, and there seems little doubt that these represent cognate xenoliths. Nevertheless, no contacts between these and the enclosing rock have been observed. This matter, however, will be discussed more fully under the heading of magmatic differentiation.

B. Structures in the Plutonic Rocks.

The plutonic rocks are all massive, and the only evidences of strain are occasional slight bending in the biotites and the well developed jointing throughout the mass.

A number of measurements have been taken on these directions of jointing, and three strikes appear to predominate, namely, N 10° E, N 65° E, and N 2° W.

It is probable that these directions bear some relation to the elongation of the bathylith, but unfortunately the intrusion cannot be viewed as a whole, and such relationships ascertained.

C. Petrography.

I. Plutonic Types.

It has been indicated previously that a gradual transition from one type into another has been noted in the field, and this has necessitated the sectioning of a great many specimens in order to confirm the field impressions.

Twelve plutonic types have been identified, and their consanguinity shown by a series of chemical analyses. On account of the passage from one group into another, however, it has been difficult in some cases to select the most suitable specimen, representative of the type, for analysis.

The chemical analyses show a range of more than 35% of SiO_2, and it is proposed to describe the rocks under the headings granite, diorite, and gabbro groups. On account of the gradation from one type into another, the granodiorite marks the transition from the granite group into the diorite and the diorite-gabbro stands between the diorite and gabbro groups. The subdivision is, of course, purely one of convenience.

(a) Granite Group.

(1) *Even-grained Biotite-granite.*

This rock represents the most acid plutonic type. It appears to surround the porphyritic biotite-granite which is confined to the region about the village of Hartley, and outcrops on the Bathurst Road and in the valley of the River Lett.

An outcrop of deep pink even-grained granite occurs near McGarry's duck-pond immediately behind the Hotel. This is medium-grained and consists chiefly of quartz and orthoclase with scattered flakes of biotite.

Further down the Lett on the northern side of the sharp bend behind the Court House, a very slightly porphyritic biotite-granite occurs and, on account of the absence of junctions, this would suggest the possibility of a transitional phase.

At the junction of the Bathurst and Jenolan Roads, and on the road to the east of the Lett Bridge, *Portion 4, Parish of Hartley*, a very coarse, even-grained type is met with. This is reddish in colour, and consists of quartz, orthoclase and biotite, the latter being a little more prominent in this rock.

Under the microscope, it is allotriomorphic granular and coarse to medium. The average grainsize of the rock outcropping on the Lett is 2–3 mm., whilst the type occurring on the road averages 4 mm. The constituent minerals are quartz, orthoclase, plagioclase, and biotite, with accessory sphene, apatite, magnetite and a little pyrites and topaz. Chlorite, kaolin, sericite, haematite, and a little myrmekite indicate both magmatic alteration and decomposition, and it has not been possible to find any specimen that does not show a certain amount of alteration. This, of course, is to be expected in so acid a type, for it represents one of the end-phases in the consolidation of the magma, in which magmatic solutions must have been very concentrated.

Orthoclase comprises about 39% of the rock and is developed in large allotriomorphic grains, which enclose or partly wrap all the other minerals. The surface is powdered with kaolin and sericite. Quartz forms about 33% of the rock. It occurs in large allotriomorphic grains with sometimes a slight suggestion of graphic intergrowth with orthoclase. Plagioclase (about 21%) forms subidiomorphic tabular crystals, and in the type behind the hotel a slightly porphyritic fabric is suggested by the occurrence of this mineral. The crystals measure up to 2 mm., and are oligoclase ($Ab_{74}An_{26}$). Biotite (roughly 6%) forms tabular flakes measuring up to 3·5 mm., though smaller flakes are more numerous. In one slide a large, partly chloritized biotite appears to be intergrown with smaller, fresher ones. Lenses of chlorite are very numerous, inclusions of apatite, sphene and iron ores are fairly numerous, and topaz has been noted in a few slides.

Though not so fresh as could be desired, the rock on the road occurs in a fairly recent cutting, and it seems likely that this represents the freshest obtainable. On this account it has been analysed, with the following results:

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	73·51	1·225	74·00	1·233	73·98	1·233	73·51	1·225
Al_2O_3 ..	14·03	0·137	14·49	0·142	13·47	0·132	15·53	0·152
Fe_2O_3 ..	0·79	0·005	1·10	0·007	0·72	0·005	2·07	0·013
FeO ..	0·91	0·013	0·45	0·007	0·97	0·014	n.d.	(0·026)
MgO ..	0·38	0·009	0·44	0·011	0·36	0·009	0·39	0·010
CaO ..	1·69	0·030	0·92	0·016	0·90	0·016	1·12	0·020
Na_2O ..	3·03	0·048	3·29	0·053	3·39	0·055	3·01	0·048
K_2O ..	4·58	0·049	4·85	0·052	4·88	0·052	4·93	0·052
H_2O+ ..	0·20	—	0·56	—	0·32	—	0·29	—
H_2O- ..	0·18	—	0·18	—	0·12	—	—	—
TiO_2 ..	0·45	0·006	0·14	0·002	0·54	0·007	—	—
P_2O_5 ..	0·05	—	0·05	—	0·05	—	—	—
MnO ..	0·01	—	0·08	0·001	0·03	—	—	—
Other Const.	—	—	0·06	—	0·10	—	—	—
Total ..	99·81		100·61		99·83		100·85	
Sp. Gr. ..	2·658		2·630		2·639			

The norms have been calculated as follows:

	I.	II.	III.	IV.
Quartz	34·68	33·60	32·88	32·94
Orthoclase	27·24	28·91	28·91	28·91
Albite	25·15	27·77	28·82	25·15
Anorthite	8·34	4·45	4·45	5·56
Corundum	1·33	2·14	0·92	3·26
Hypersthene	1·16	1·10	1·16	4·43
Magnetite	1·16	1·39	1·16	—
Ilmenite	0·91	0·30	1·06	—
Haematite	—	0·16	—	—

I. Even-grained Biotite-granite. Bathurst Road, Hartley. [Toscanose, I, (3)4, 2, 3]. Anal. G. A. Joplin.

II. Aplitic Granite. Tenterfield, New England, N.S.W. [Toscanose, I, (3)4, (1)2, 3]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii, 1907, p. 225. *In* Washington's Tables, p. 212, No. 360.

III. Granite. Bolivia, New England, N.S.W. [Toscanose, I, (3)4, (1)2, 3]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii, p. 220, 1907. In W.T., p. 212, No. 361.

IV. Granite. Serrerhof, n. Wolfach-Schwarzwald. [Toscanose, I, (3)4, "2, 3]. Anal. H. Schwenkel, in Diss. Tüb., p. 146, 1912. In W.T., p. 199, No. 241.

(ii). *Porphyritic Biotite-granite.*

This occurs along the Bathurst Road in the village of Hartley, and is met with on the hillside above the road to the south, and in the bed of the River Lett to the north.

The rock is of a greyish colour, with large, tabular, pale pink phenocrysts of orthoclase up to an inch in length. Simple twinning is often well developed. The groundmass is fairly coarse, and in the handspecimen can be seen to consist of quartz, plagioclase, biotite and a little orthoclase. Sphene may also be frequently detected macroscopically, and iron pyrites is abundant along joint planes.

Under the microscope the groundmass is seen to be allotriomorphic granular, and to be composed of quartz, plagioclase, orthoclase, and biotite, with accessory sphene, magnetite, and a little muscovite and myrmekite. Small quantities of chlorite, haematite and kaolin occur as alteration products.

The large orthoclase crystals measure up to 20 mm., and show slight microperthitic intergrowth with albite. These phenocrysts contain inclusions of quartz, plagioclase, sphene, biotite, and apatite, and there appears to be a kind of marginal parallel intergrowth with plagioclase. Orthoclase forms about 41% of the rock.

In the groundmass orthoclase is subordinate to quartz and plagioclase, and allotriomorphic grains measure about 1·5 mm. Microperthitic intergrowth is apparent, and where orthoclase is in contact with plagioclase there is an occasional slight development of myrmekite.

Quartz forms about 25% of the rock, and a few irregular grains, measuring up to 8 mm., occur as phenocrysts, but this mineral is most commonly developed in the groundmass, where grains average 1·5 mm. Some of these sections show a subidiomorphic "arrow-shape", which characterizes graphic intergrowth, though

this structure cannot be said to be present. One large rounded equidimensional grain 3 mm. across was noticed, containing radial inclusions of orthoclase, and biotite occasionally forms inclusions in the smaller grains.

Plagioclase ($Ab_{71}An_{29}$) forms subidiomorphic tabular crystals up to 3 mm., and comprises about 20% of the rock. Crystals are often zoned, and sometimes show poorly developed pericline twinning in addition to the well developed albite lamellae.

Biotite is moderately abundant in the groundmass (13%), and small flakes averaging 0·3 mm. are often segregated into masses which measure 2 mm. across. The flakes are mostly idiomorphic and often show cracks and slight bending, whilst the smaller flakes are often much chloritized. Apatite inclusions are very numerous, and are usually oriented in such a way that their longer axes are parallel to the cleavage of the biotite. Inclusions of felspar, magnetite and sphene are also fairly common in the biotite. Sphene is very well developed as an accessory mineral, and is idiomorphic to subidiomorphic. The average grainsize is about 1 mm., though larger crystals have been detected in the handspecimens. A few perfect lozenge-shaped crystals measuring 0·6 mm. are included in an orthoclase phenocryst. Magnetite forms irregular grains, and is included in the felspars and biotites. This usually forms a kind of intergrowth with sphene, but as the latter appears to be primary, there is no justification for assuming the iron ore to be ilmenite, and the appearance is probably due to a simultaneous crystallization of magnetite and sphene. Apatite forms large crystals up to 1 mm., but quite small inclusions in biotite are more common. Primary epidote and allanite have also been found in a slide of this rock.

A chemical analysis has been made of this type, but it has not been possible to compare it with the Bathurst porphyritic biotite-granite, as a complete analysis of this rock has not been obtainable. W. J. Clunies Ross (1894) quotes 68% for SiO_2 and specific gravity 2·75–2·79 for the Bathurst rock.

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	68·60	1·143	68·25	1·138	69·01	1·150	68·20	1·136
Al_2O_3 ..	15·33	0·150	14·41	0·141	15·44	0·151	15·99	0·157
Fe_2O_3 ..	1·92	0·012	2·00	0·013	1·28	0·008	0·89	0·006
FeO ..	1·85	0·026	2·07	0·029	1·28	0·018	2·58	0·036
MgO ..	0·81	0·020	1·08	0·027	0·62	0·016	0·80	0·020
CaO ..	2·78	0·050	3·06	0·055	2·54	0·045	2·61	0·046
Na_2O ..	3·38	0·055	3·19	0·052	3·85	0·062	2·85	0·045
K_2O ..	4·52	0·048	4·74	0·050	4·52	0·048	4·60	0·049
H_2O+ ..	0·50	—	0·35	—	0·56	—	0·64	—
H_2O- ..	0·11	—	0·19	—	0·33	—	0·21	—
TiO_2 ..	0·51	0·006	0·36	0·005	0·49	0·006	0·58	0·008
P_2O_5 ..	0·22	0·001	0·15	0·001	0·24	0·002	0·14	0·001
MnO ..	0·04	—	0·16	0·002	0·01	—	0·04	—
Other Const.	—	—	0·09	—	—	—	0·15	—
Total ..	100·57		100·10		100·17		100·28	
Sp. Gr. ..	2·703		2·698		2·664		2·673	

	I.	II.	III.	IV.
Quartz	24·18	23·70	23·64	26·64
Orthoclase	26·69	27·80	26·69	27·80
Albite	28·82	27·25	32·49	28·58
Anorthite	13·07	10·84	10·56	11·95
Corundum	—	—	0·31	2·04
Diopside	—	2·94	2·13	—
Hypersthene	3·06	2·99	—	4·90
Magnetite	2·78	3·02	1·86	1·39
Ilmenite	0·91	0·76	0·91	1·22
Apatite	0·34	0·34	0·67	0·34

I. Porphyritic Biotite-granite. Bathurst Road, Por. 14, Parish of Hartley. [Toscanose, I", 4, 2", 3]. Anal. G. A. Joplin.

II. Granite. Herding Yard Creek, N.S.W. [Toscanose, I(II), 4, 2, 3]. Anal. W. A. Greig, *Geol. Surv. N.S.W., Min. Res.*, No. 14, 1911, p. 90.

III. Quartz-monzonite. Lone Pine Creek, Mount Whitney Quadrangle, California. [Toscanose, I, 4, 2, 3"]. Anal. R. C. Wells, U.S.G.S. Rec. Lab. In W.T., p. 186, No. 146.

IV. Porphyritic Granite. Granite Island, Encounter Bay, South Australia. [Toscanose, I", 4, 2", 3]. Anal. W. R. Browne, *Trans. Roy. Soc. S. Aust.*, 1920.

(iii). *Hornblende-biotite-granite.*

This type is, perhaps, the most abundantly developed in the area examined. It is met with on the River Lett between the bridges, where it grades into a granodiorite to the south, and into a biotite-granite to the north. This rock is a massive, coarse-grained, pinkish-grey type in which quartz, orthoclase, biotite, hornblende and plagioclase may be distinguished in the handspecimen. An almost identical type occurs on Campbell's Creek, and this gradually becomes more basic and passes into a granodiorite at the junction of the creek with Cox's River.

A hornblende-biotite-granite, of slightly finer texture and lighter colour, is met with at the junction of Moyne Creek and Grant's Creek, and this passes into a darker and coarser type towards the south. This latter outcrops near the mouth of Kanimbla Creek, and is found to be very similar to, though slightly darker than, the rock occurring on the River Lett. In this type, the plagioclase is of a yellowish-green colour and, on account of its abundance, and of the darker colour of the rock, it seems that the rock stands very close to a granodiorite.

Under the microscope, the hornblende-biotite-granites are seen to be allotriomorphic-granular with a medium grainsize, averaging 2–3 mm. The minerals present are quartz, orthoclase, plagioclase, hornblende and biotite, with accessory magnetite, sphene and apatite. In addition, the Lett River rock contains a small quantity of epidote, rutile and chlorite.

The quartz forms about 26·5% of the rock and occurs in allotriomorphic grains varying from 1 mm. to 3 mm. in size. Slight granulation and minute inclusions, some of which appear to be liquid, occur in the quartz of the Grant's Creek type; and in the Lett type quartz is both included in, and includes, orthoclase, whilst a parallel development of the hornblende is evinced by a slight graphic intergrowth between that mineral and quartz. Orthoclase forms allotriomorphic grains up to 3 mm., and usually shows microperthitic intergrowth with albite. Orthoclase apparently started to crystallize at the same time as quartz,

and continued to grow after the quartz had finished, since some of the larger grains are interstitial. About 35% of the rock is composed of this mineral. The plagioclase is oligoclase ($Ab_{70}An_{30}$). It forms subidiomorphic sections averaging 1–3 mm., and is much less abundant than orthoclase, forming about 25% of the rock. Zoning is often developed, albite twinning is well marked, and some sections show pericline twinning. Rutile needles form schiller inclusions in the Lett type and epidote is present in decomposition zones. Hornblende is well developed (about 10% of the rock). In the Kanimbla type, columnar crystals measure up to 3·25 mm. The average size of hornblende crystals, however, is from 1 to 2 mm., and the mineral usually forms subidiomorphic prisms. Inclusions of apatite, sphene, biotite, felspar and iron ores are numerous and, as has been pointed out, a kind of graphic intergrowth of hornblende with quartz occurs in the Lett type. Some of the hornblende in this rock is rather pale, and may be secondary. Biotite is well developed (some 4·5%) as subidiomorphic flakes, which measure up to 2 mm., and sometimes form aggregates of small shreds averaging about 0·5 mm. Inclusions of iron ore, apatite and sphene are fairly numerous, and chlorite often occurs in lenses parallel to the cleavage. The mineral is strongly pleochroic, and in the more acid type on Grant's Creek, pleochroic haloes are fairly abundant. It is probable that the nuclei are zircons, but this mineral has not been identified.

Magnetite is moderately abundant as an accessory and often forms the centre of a phenocryst, which is bordered by a fringe of biotite, and measures 0·5 mm. across. This is a common feature of the Grant's Creek type. Magnetite forms irregular grains and sometimes is intergrown with sphene, hence some of the iron ore is, perhaps, ilmenite. Sphene occurs both as idiomorphic crystals measuring up to 0·25 mm., and more frequently as allotriomorphic grains wrapping round, and intergrown with, hornblende and iron ores. Occasionally iron ore is included in sphene. Apatite forms small, stumpy prisms and is included in all the other minerals. Topaz has been detected in one slide of the Lett type.

(iv). *Granodiorite.*

This type occurs at the junction of Campbell's Creek and Cox's River, where it has been shown to merge into the hornblende-biotite-granite to the north. Granodiorites are also met with along Kanimbla Creek and Spring Creek. The granodiorite on Campbell's Creek is very similar to the hornblende-biotite-granite to the north, that is, it is a massive, fairly coarse, pinkish-grey rock, consisting of quartz, orthoclase, plagioclase, hornblende and biotite. Though the general body-colour of the rock is almost identical with the more acid type to the north, a close examination reveals the fact that hornblende and plagioclase are a little more plentiful in the granodiorite. This rock is characterized by an abundance of basic segregations averaging about one and a half inches across. One of these has been sectioned and is described later.

Under the microscope, the granodiorite from Campbell's Creek is seen to consist of quartz, plagioclase, orthoclase, hornblende and biotite, with accessory magnetite, sphene, apatite and a little chlorite and kaolin as alteration products.

The rock is hypidiomorphic to allotriomorphic granular with a fairly even grainsize of about 2 mm. Quartz forms about 29% of the rock and occurs in allotriomorphic grains from 1·5 mm. to 3 mm. It contains inclusions of felspar. The plagioclase comprises about 36% of the rock and is andesine ($Ab_{65}An_{35}$). It shows zoning in addition to albite and pericline twinning, and tabular sub-

idiomorphic crystals vary from 3 mm. to 1·5 mm. Orthoclase (about 20·5%) forms allotriomorphic grains varying from 1 mm. to 3 mm., and is slightly microperthitic. Inclusions of hornblende, biotite, sphene, apatite and quartz are fairly numerous. Biotite forms subidiomorphic flakes, a few large ones measuring 2 by 3 mm. It is strongly pleochroic, and shows a slight marginal intergrowth with hornblende. Some smaller flakes show alteration into chlorite which forms lenses parallel to their cleavages. Inclusions of iron ore, felspar, sphene and apatite are fairly abundant. This mineral forms about 11% of the rock.

Hornblende (3%) forms subidiomorphic prisms about 1 mm. in length and, though apparently primary, is of a pale-green colour. A slight intergrowth with biotite is present, and inclusions of sphene, apatite and magnetite are fairly numerous.

Sphene is moderately abundant, and is of a reddish-purple colour. It is associated with iron ore, and included in ferromagnesian minerals and felspars. Magnetite forms grains from 0·5 mm. to 0·1 mm., and is fairly abundant as an accessory. Apatite is present as inclusions.

The rock has been analysed, with the following result:

	I.	Ia.	II.	IIa.	III.	IIIa.	IV.	IVa.
SiO_2 ..	65·33	1·088	65·83	1·097	64·04	1·067	65·36	1·089
Al_2O_3 ..	16·20	0·159	16·44	0·161	15·58	0·153	16·37	0·161
Fe_2O_3 ..	2·43	0·015	1·03	0·006	0·80	0·005	1·80	0·011
FeO ..	2·38	0·033	3·33	0·046	4·47	0·062	2·68	0·038
MgO ..	1·28	0·032	2·00	0·050	2·64	0·066	1·81	0·045
CaO ..	4·02	0·071	4·24	0·076	3·52	0·063	3·82	0·068
Na_2O ..	3·02	0·048	2·25	0·036	2·42	0·039	3·40	0·055
K_2O ..	3·28	0·035	3·40	0·036	2·80	0·030	3·75	0·039
H_2O+ ..	0·58	—	0·67	—	2·25	—	0·33	—
H_2O- ..	0·10	—	0·10	—	0·38	—	0·09	—
TiO_2 ..	0·72	0·009	0·78	0·009	0·80	0·010	0·36	0·005
P_2O_5 ..	0·22	0·001	0·21	0·001	0·18	0·001	0·16	0·001
MnO ..	0·03	—	0·08	0·001	—	—	0·16	0·002
Other Const.	—	—	—	—	—	—	0·33	0·010
Total ..	99·59		100·36		99·88		100·35	
Sp. Gr ..	2·742		2·741		2·722		2·711	

	I.	II.	III.
Quartz ..	24·78	26·22	25·14
Orthoclase	19·46	20·02	16·68
Albite ..	25·15	18·86	20·44
Anorthite	18·90	20·29	16·68
Corundum	0·82	1·63	2·45
Hypersthene	4·39	9·22	12·94
Magnetite	3·48	1·39	1·16
Ilmenite..	1·37	1·37	1·52
Apatite ..	0·34	0·34	0·34

I. Granodiorite. Junction of Campbell's Ck. and Cox's River, Hartley. [Amiatose, I(II), 4, 3, 3″]. Anal. G. A. Joplin.

II. Granodiorite. Por. 48, Parish of Moruya. [Amiatose, I(II), 4, 3, 3]. Anal. Ida A. Brown, Proc. Linn. Soc. N.S.W., 1928.

III. Granodiorite. Near Braemar House, Mt. Macedon, Victoria. [Harzose, ″II, ″4, 3, 3]. Anal. R. J. Lewis, *Bull. Geol. Surv. Vict.*, 24, 1912, p. 20.

IV. "Blue Granite". Tenterfield, New England, N.S.W. [Amiatose, I(II), 4, (2)3, 3″]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii (3), 1907, p. 203. In W.T., p. 252, No. 54.

(b). Diorite Group.

(v). *Tonalites.*

The tonalites are the most acid members of the diorite group. These outcrop on Moyne Farm, where they form the central, more acid differentiate of the intrusion. The tonalites grade almost imperceptibly into the quartz-mica-diorites by a decrease in orthoclase and quartz and an increase in the ferromagnesian constituents, and in the basicity of the plagioclase.

In the handspecimen, the tonalites appear as fairly fine-grained, massive, grey or pinkish-grey rocks with about equal proportions of light and dark constituents. With the aid of the lens, the light minerals can be distinguished as colourless or smoky quartz, white plagioclase, and pale-pink orthoclase, whilst the dark minerals comprise hornblende and biotite and sometimes fairly large patches of green epidote. Small aplite veins varying from half an inch to mere threads are very abundant, and these have produced a local monzonitic fabric in the contiguous rock.

Under the microscope, the tonalites are found to be holocrystalline and hypidiomorphic to allotriomorphic granular, with a tendency towards subophitic fabric in some cases. The grainsize is even and averages about 2 mm. The rock consists of plagioclase, quartz, biotite, hornblende and orthoclase, with accessory iron ores, sphene, epidote, apatite and occasionally carbonates, sericite, chlorite, kaolin and rutile. Most of the hornblende is due to reaction and a few cores of pyroxene have been detected.

The plagioclase which is andesine ($Ab_{68}An_{32}$) forms subidiomorphic tabular crystals with a lath-like tendency, and varies from 1 mm. to 3 mm. in size. A slight magmatic alteration has caused sericitization and kaolinization of the felspars. Albite twinning and zoning are well developed. About 57% of the rock is plagioclase. The quartz (some 16·5%) is in allotriomorphic grains, and though interstitial, it is not so markedly so as in the quartz-mica-diorites. The consolidation has apparently been in part contemporaneous with that of plagioclase. In several cases a kind of intergrowth between quartz and uralitic hornblende has been observed. On an average the quartz grains in the body of the rock are 1–2 mm., but minute grains are present in quartz veins, which ramify through the tonalites. Hornblende (about 11%) is both primary and uralitic after pyroxene, but the latter type is the more abundant. Simple twinning is often shown and good amphibole cleavage is apparent in some sections. The uralite pseudomorphs are usually fringed with biotite and include secondary magnetite, epidote and sphene.

In one slide a frayed and tufted amphibole occurs in small quantity, and this may be of the nature of actinolite. In another specimen fragments of horn-

blende, quartz, felspar and chlorite form a kind of groundmass, enwrapping larger mineral individuals. The hornblende contains numerous inclusions of iron ore, apatite and sphene, and is intimately associated with chloritized biotite and epidote.

Biotite is often more abundant than hornblende, but varies in quantity in different parts of the mass. This is probably due to local variations of physical conditions during consolidation, and as a result a certain amount of heterogeneity has been set up. The average amount, like hornblende, is about 11%. The biotite forms subidiomorphic flakes up to 1·5 mm., but most frequently occurs in small flakes which are aggregated together into masses, measuring up to 3 mm. across.

Inclusions of iron ores, apatite and sphene are common, and in one slide granules of secondary sphene and iron ore, evidently ilmenite, are strung out along the biotite cleavages. Where the biotite shows bending, these granular strings are seen to follow it. Small needles of rutile, arranged parallel to the cleavage, are also present in this slide. Lenses of chlorite are numerous, and in some cases the biotite appears to have been entirely chloritized by magmatic solutions. A slight intergrowth with uralitic hornblende is present in a few slides. Both primary and secondary sphene occur, but the latter is the more abundant. It is usually found as inclusions in the ferromagnesian minerals, and also surrounding and associated with ilmenite grains. Epidote is fairly abundant, and much appears to be primary or at least deuteric. Grains measure up to 0·2 mm. and are in association with the ferromagnesian minerals. In one slide subidiomorphic prisms measure up to 0·65 mm. and are grouped. Orthoclase is usually subordinate, but gains prominence in the neighbourhood of aplitic veins. Iron ores appear to comprise both magnetite and ilmenite, and are fairly abundant accessories. Apatite is a constant inclusion mineral and forms prisms up to 0·3 mm.

No specimen has been found entirely free from deuteric alteration, and due allowance must be made for this in the analysis.

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	62·06	1·034	61·61	1·027	61·44	1·024
Al_2O_3	18·25	0·177	17·95	0·176	17·61	0·178
Fe_2O_3	2·91	0·018	3·85	0·021	1·86	0·011
FeO	2·94	0·040	3·38	0·047	3·59	0·050
MgO	1·71	0·043	2·09	0·052	3·09	0·077
CaO	4·90	0·088	4·91	0·088	5·88	0·105
Na_2O	3·12	0·050	3·22	0·052	2·03	0·032
K_2O	1·61	0·017	1·04	0·011	1·03	0·012
H_2O+	1·34	—	1·50	—	1·17	—
H_2O-	0·16	—	—	—	0·10	—
TiO_2	0·60	0·008	0·37	0·005	1·42	0·018
P_2O_5	0·24	0·001	0·19	0·001	0·33	0·002
MnO	0·09	0·001	—	—	0·09	0·001
Total	99·93		99·71		99·64	
Sp. Gr.	2·764		—		2·768	

	I.	II.	III.
Quartz	24·12	24·36	27·72
Orthoclase	9·45	6·12	6·67
Albite	26·20	27·25	16·77
Anorthite	23·63	28·63	27·24
Corundum	2·65	2·86	3·16
Hypersthene	6·28	7·97	10·60
Magnetite	4·18	4·87	2·55
Ilmenite..	1·22	0·76	2·74
Apatite	0·34	0·34	0·67

I. Tonalite. Moyne Farm, Little Hartley. [Yellowstonose, near Tonalose, (I)II, 4, 3, 4]. Anal. G. A. Joplin.

II. Andesite (quartzose). Martinique, West Indies. [Tonalose, (I)II, 4, 3", 4"]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 531. In W.T., p. 384, No. 114.

III. Quartz-diorite (Tonalite). Kelly's Point, 10 miles south-east of Moruya. [Bandose, near Tonalose, 'II, (3)4, '4, 4]. Anal. Ida A. Brown, Proc. Linn. Soc. N.S.W., 1928.

(iv). *Monzonitic Quartz-diorite.*

It has been pointed out that certain of the tonalites might be put down as monzonites from the microscopic examination alone, but field-relations have shown that these rocks occur in the neighbourhood of aplite veins, and that the monzonitic fabric is only of very local occurrence.

On Kanimbla Station, however, a very coarse type of quartz-monzonite occurs, but through the presence of alluvium its field-relations cannot be ascertained. The rock occurs in the bed of Kanimbla Creek and the whole outcrop is only a couple of chains in diameter. On account of its coarse and massive texture, the rock weathers into huge tors, and the outcrop is most distinctive. This rock may be of only local occurrence, but its origin is certainly different from that of the monzonitic tonalites, whose extent is but a matter of centimetres.

Much consideration has been given to the naming of this rock, and it has been decided for the present to call it a monzonitic quartz-diorite, rather than a quartz-monzonite. The latter would imply a distinct group, which some authors (Harker, and Hatch and Wells) place as intermediate between the diorites and syenites, and it will be shown later that the Hartley complex is typical of the granite-granodiorite differentiation as outlined by Bowen (1915).

Though the quartz-monzonites show affinities for this line of descent, other difficulties present themselves. Firstly, the Hartley rock has a silica percentage much lower than the typical quartz-monzonites (Hatch and Wells, 1926). Secondly, the rock may be a local differentiate only, and would hardly warrant the introduction of another group-name. Thirdly, the scheme of classification outlined by Iddings (1909) necessitates exact measurements, either by a Rosiwal analysis, or by calculation from the chemical analysis. It has not been possible to make exact quantitative measurements, and as the composition of the ferromagnesian minerals is unknown, a calculation of the mineral composition is also impossible. Monzonitic affinities, however, are exemplified somewhat by the magmatic name, which is Harzose near Shoshonose. This latter is the subrang of many of the South Coast latites (Card, 1915).

In the handspecimen the rock is holocrystalline, very coarse, and of a greyish-pink colour. It can be seen to consist of white plagioclase showing excellent multiple twinning, large plates of black biotite, colourless quartz grains, pink orthoclase, which often can be seen wrapping plagioclase, and producing a monzonitic fabric, and a little hornblende.

Under the microscope the rock is holocrystalline and hypidiomorphic to allotriomorphic granular, with a distinct tendency to monzonitic fabric. The grainsize is coarse and averages 7 mm. It consists of plagioclase, orthoclase, quartz, biotite, hornblende, iron ores, sphene, apatite, and a little rutile.

Plagioclase forms about 60% of the rock and is present in subidiomorphic, tabular crystals, 2–8 mm. in length. It is andesine of the composition $Ab_{64}An_{36}$. Albite and pericline twinning are both well developed, and the surface is a little kaolinized and sericitized. Inclusions of sphene, biotite, iron ores and apatite are present, and in some cases a slight zoning by inclusions is apparent. Orthoclase forms interstitial allotriomorphic grains up to 6 mm., and comprises some 26% of the rock. This mineral contains inclusions of all the others present in the rock, and is rather kaolinized. A certain amount of intergrowth with albite is present, and kaolinization has been selective in being more abundant in the soda-felspar. Quartz (about 8% of the rock) forms smaller grains than orthoclase, but is more abundantly developed. It too is interstitial, but slightly precedes orthoclase in final consolidation. Grains measure up to 1·5 mm. Biotite (about 2%) is a brown, strongly pleochroic variety, and tabular flakes measure up to 2 mm. across. Inclusions of apatite and felspar are fairly numerous, and there is some intergrowth with hornblende. Peculiar suture-like cracks are developed in some cases, and these must have been produced by strains during consolidation. A little chlorite is found as an alteration-product. Hornblende (about 2·5%) forms subidiomorphic prisms measuring 1·5 mm., and is slightly intergrown with biotite. Inclusions of apatite, felspar, sphene, iron ores and a little rutile are present, and chlorite is often associated as an alteration product. Primary sphene occurs mainly as irregular grain inclusions, but is not abundant. A small quantity of secondary sphene is associated with the iron ores, which apparently consist of both magnetite and ilmenite.

The analysis of this rock is given below:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	58·37	0·973	58·20	0·970	59·94	0·994
Al_2O_3	18·38	0·180	18·35	0·180	15·61	0·153
Fe_2O_3	2·80	0·018	1·44	0·009	1·55	0·010
FeO	4·43	0·061	3·46	0·048	6·25	0·087
MgO	2·79	0·069	3·49	0·087	2·53	0·063
CaO	6·29	0·113	6·20	0·111	6·65	0·119
Na_2O	2·52	0·040	2·63	0·042	2·88	0·047
K_2O	2·56	0·028	2·96	0·032	2·06	0·022
H_2O+	0·56	—	2·05	—	0·57	—
H_2O-	0·16	—	—	—	0·39	—
TiO_2	0·52	0·006	0·87	0·011	1·08	0·014
P_2O_5	0·26	0·002	—	—	0·64	0·004
MnO	0·06	0·001	0·35	0·005	—	—
Total	99·70		100·00		100·15	
Sp. Gr.	2·807					

	I.	II.	III.
Quartz	14·76	11·34	15·78
Orthoclase	15·57	17·79	12·23
Albite	20·96	20·01	24·63
Anorthite	29·47	29·47	23·35
Corundum	0·20	—	—
Diopside..	—	1·11	5·35
Hypersthene	11·92	12·52	11·93
Magnetite	4·18	2·09	2·32
Ilmenite..	0·91	1·67	2·13
Apatite	0·67	—	1·34

I. Monzonitic Quartz-diorite. Kanimbla Station, Little Hartley. [Harzose, "II, 4", 3(4), 3"]. Anal. G. A. Joplin.

II. Andesite. St. Paul's, Whangaroa, N.Z. [Harzose, "II, 4(5), (2)3, 3"]. Anal. J. S. Maclaurin, Bell and Clarke, *Bull. N.Z. Geol. Surv.*, 8, 1909, p. 68. In W.T., p. 368, No. 84.

III. Granodiorite. Glenrock Falls, Marulan. [Bandose]. Anal. G. J. Burrows, PROC. LINN. SOC. N.S.W., xxxiv, 1909.

(vii). *Quartz-mica-diorites.*

Quartz-mica-diorites occur bordering both the Moyne Farm and Cox's River intrusions.

On Moyne Farm, this type merges imperceptibly into the tonalite by a gradual decrease in the ferromagnesian minerals, and an increase in the acidity of the plagioclase. The coming in of orthoclase also marks the transition into the tonalite. At the contact with the Devonian strata, the rock is finer grained and no hornblende has been detected. Masses of alteration-products, however, may represent remnants of this mineral.

On the Cox's River, the quartz-mica-diorites gradually become more basic away from the margin and pass into a diorite-gabbro, which in turn passes into a central mass of gabbro. It seems probable that the quartz-mica-diorites have suffered some contamination and that the diorite-gabbro is a reaction border of the gabbro. The analysis shows that the Cox's River quartz-mica-diorites are a little more basic than the Moyne Farm type, though there is no essential difference in the mineral composition. The rock near the contact with the Devonian strata is usually somewhat porphyritic in plagioclase.

The quartz-mica-diorites have a typical dioritic appearance, light and dark constituents being present in about equal abundance. With the aid of a lens, quartz and biotite may be distinguished in addition to the plagioclase and hornblende.

Under the microscope the rock is hypidiomorphic to panidiomorphic granular, and the fabric is ophitic to subophitic, and sometimes poikilitic. The mineral constituents are plagioclase, biotite, hornblende, quartz and, in some cases, uralitized pyroxene with occasional cores of augite. A little orthoclase is sometimes present in the Moyne type. Accessory minerals are magnetite, ilmenite, apatite and rutile. Epidote, α-zoisite, saussurite, sericite, kaolin, rutile and sphene are deuteric and secondary.

Some of the slides show a mineral that has not been satisfactorily identified, but may possibly be lawsonite. It is found forming lenses in the biotite, and has

often caused slight bending in the mica. It appears to be in parallel intergrowth with the biotite, and seems to consist of an aggregate of fibres that are parallel to the biotite cleavage. It has a double refraction about 0·020, and has a medium refractive index, but other optical properties cannot be obtained owing to the fibrous nature of the mineral. Dr. Stillwell has described an apparently similar mineral as lawsonite in an actinolite-schist from Adélie Land, Antarctica, and of this he says: "The colourless mineral is frequently found in parallel intergrowth with biotite. Sometimes it is so developed after this manner that the biotite appears to be merely threaded in along cleavage planes. Its form is usually lobate, and the biotite plates, in consequence, bend round its contour. Its cleavage is well developed parallel to the elongation of the crystal, and the cleavage of the biotite."

It seems likely that the mineral of the Hartley rock is the same, though no evidence of metamorphism has been observed. There is little doubt, however, that the Hartley rocks have suffered deuteric alteration, and it may be possible that lawsonite, like epidote, may be a deuteric as well as a metamorphic mineral.

With regard to the occurrence of lawsonite, Iddings (1911) says: "It has been found in a number of localities in Italy, accompanying albite and saussuritized felspar."

Plagioclase (about 57·5% of the rock) occurs in elongated tabular sections or laths, and varies from 0·75 mm. to 2 mm. It is andesine, which on Moyne Farm ranges from $Ab_{55}An_{45}$, at the margin of the intrusion, to $Ab_{64}An_{36}$ as the quartz mica-diorite passes into the tonalite. On the Cox the range is from $Ab_{58}An_{42}$ to $Ab_{40}An_{60}$ where the rock merges into the diorite-gabbro (see Text-figs. 6 and 7). Albite and pericline twinning are well developed and zoning is fairly common. Some sections show tabular felspars crowded with inclusions of biotite, hornblende, epidote and iron ores. These are concentrated towards the centre of the felspar, and there is an outer border of sericite, kaolin and other alteration products of the felspar. The included biotites are usually oriented in such a way that their longer axes are parallel to that of their host.

One of the Moyne Farm rocks and a great many of the marginal rocks of the Cox intrusion are porphyritic in plagioclase. Tabular, zoned phenocrysts measuring 3 mm. across are set in a typical quartz-mica-diorite groundmass with an average grainsize of 0·15 mm. A somewhat similar type occurs on Kanimbla Creek on the property of Mr. Hughes. All three porphyritic types are somewhat similar to a porphyritic granodiorite (M 127b) described by Miss Ida A. Brown (1928) from Moruya.

As is the case with the tonalites, sometimes biotite, and sometimes hornblende is the more abundant ferromagnesian mineral. Evidently local conditions have favoured the formation of either one or the other. Hornblende (about 16% of the rock) usually forms subidiomorphic plates wrapping plagioclase, and thus producing an ophitic fabric. In some cases almost idiomorphic columnar sections occur, and in one of the Moyne specimens granular aggregates of hornblende are present as well as subidiomorphic individuals. In several slides a kind of poikilitic fabric is produced by optically continuous masses of hornblende up to 3 mm. across, which includes felspars, iron ores, epidote, apatite, biotite and chlorite. Inclusions of the accessory minerals are common in the hornblende of all the specimens. Some sections show an intergrowth of hornblende and biotite, and others masses of secondary amphibole bordered by primary hornblende and biotite, and usually enclosing pyroxene cores. Biotite (averaging about 10·5% of

the rock) is sometimes developed in subidiomorphic, tabular flakes up to 3 mm. across, but averages about 1 mm. The larger sheets enclose most of the other minerals, giving a kind of poikilitic fabric, and this structure is sometimes developed to a marked degree. Bending is often present, and lenses of lawsonite (?) are fairly numerous, especially in the Cox's River specimens. Intergrowth of biotite and hornblende is not infrequent, particularly around cores of amphibolized pyroxene.

Inclusions of the accessory minerals are abundant in the biotite, and comprise ilmenite, magnetite and apatite. In one of the Moyne slides a few small reddish-brown haloes are present, and these possibly surround small zircons. Ilmenite and secondary sphene often form little granular strings in the mica. Lenses of chlorite are numerous and in places the biotite appears to have been almost entirely chloritized. Other alteration products of the mica are grains of epidote and secondary magnetite, which appear to be concentrated towards the margin. The original biotite evidently contained a fairly large proportion of titania, since sagenite webs are very well developed in a few slides.

Quartz (some 12% of the rock) forms allotriomorphic grains and is always interstitial. The size of the grains varies with the texture of the rock, ranging from 0·1 mm. to 1·5 mm. Owing to its interstitial occurrence, a kind of poikilitic fabric is produced. In a few slides from both intrusions small plagioclase laths are enclosed in this way, and at first glance it appears to be almost a graphic intergrowth of quartz and plagioclase; the latter, however, are not oriented. Small groups of quartz grains often show mosaic granular aggregates. Inclusions are very numerous in the quartz, but are usually very small. Some of these have been identified as apatite, ilmenite, magnetite and rutile, but the majority are ultra-microscopic. Slight granulation is sometimes present, and in a few cases undulose extinction has been noted. Small quartz veins are fairly numerous. In some cases they merge into the body of the rock, and were evidently injected whilst it was still hot, and only partly solidified. On the other hand, some of these small veins show evidence of having been injected into the cold rock.

Orthoclase is present in a few of the Moyne rocks, but it is not a common constituent, and is developed only in small amount.

The iron ores consist of both ilmenite and magnetite, and are abundant as accessories, and comprise about 4% of the rock. Magnetite usually forms sub-rectangular grains measuring about 0·2 mm., and in one slide grains are bordered by clear, transparent, red haematite. Secondary sphene forms small granules bordering ilmenite, and is abundant in most of the slides. The iron ores occur mainly as inclusions, but in some cases appear to be intergrown with the ferro-magnesian minerals. Small grains of secondary magnetite are commonly associated with biotite and amphibolized pyroxene. Rutile is mostly secondary, but a primary origin must surely be postulated for the needles included in the quartz. Apatite is a constant inclusion mineral, and forms both stumpy prisms and long slender needles. Cross-partings are well developed in the latter.

The occurrence of epidote, α-zoisite, saussurite, sericite, kaolin and secondary sphene, magnetite and rutile would indicate that the rocks have suffered a certain amount of deuteric alteration. Epidote usually occurs in irregular grains associated with biotite or hornblende and occasionally with felspar. In some cases subidiomorphic prisms occur, and these appear to be irrefutable evidence of a

deuteric, rather than a secondary origin. A little α-zoisite intergrown with epidote and associated with plagioclase is present in one of the Moyne rocks; and in another it is associated with calcite, epidote, etc., in a mass of saussurite.

Masses of alteration products consisting largely of sericite, carbonates and chlorite are very numerous in the rock from the contact with the Devonian strata on Moyne Creek. These are apparently pseudomorphs after some mineral. Hornblende is conspicuously absent, and some of the pseudomorphs suggest hornblende in form, so this was possibly the original mineral.

Two chemical analyses have been made of the quartz-mica-diorites, one from the Moyne intrusion, and one from Cox's River. In both cases the freshest and most representative specimen has been chosen, but as in the case of the tonalites, due allowance must be made for deuteric alteration. Moreover, on account of the gradations of one type into another, and of the possibility of contamination, single analyses give a poor picture of the true composition of the original magma.

The analysis of the Moyne type is given in column I below:

	I	Ia.	II.	IIa.	III.	IIIa.
SiO_2	54·37	0·900	55·42	0·924	55·16	0·919
Al_2O_3	19·64	0·192	21·35	0·209	17·51	0·174
Fe_2O_3	4·30	0·027	3·37	0·021	2·62	0·016
FeO	4·87	0·068	4·87	0·068	5·83	0·081
MgO	2·94	0·073	3·87	0·097	4·35	0·100
CaO	8·07	0·143	7·51	0·134	8·50	0·145
Na_2O	2·55	0·040	2·94	0·047	1·83	0·029
K_2O	1·01	0·011	0·68	0·007	1·08	0·012
H_2O+	0·96	—	0·37	—	2·01	—
H_2O-	0·11	—	—	—	0·18	—
TiO_2	1·14	0·014	0·33	0·004	0·64	0·008
P_2O_5	0·34	0·002	tr.	—	0·21	0·002
MnO	0·07	0·001	—	—	0·15	0·002
Other Const.	—	—	—	—	0·10	—
Total	100·37		100·71		100·17	
Sp. Gr.	2·861				2·902	

	I.	II.	III.
Quartz	13·14	11·52	13·98
Orthoclase	6·12	3·89	6·67
Albite	20·96	24·63	15·20
Anorthite	38·09	37·25	36·97
Corundum	0·41	2·14	—
Diopside..	—	—	1·36
Hypersthene	11·00	15·38	18·02
Magnetite	6·26	4·87	3·71
Ilmenite..	2·13	0·61	1·22
Apatite	0·67	—	0·67

I. Quartz-mica-diorite. Moyne Farm, Little Hartley. [Bandose, II, 4", 4, 4]. Anal. G. A. Joplin.

II. Diabase (inclusion in Andesite). Mont Pélée, Martinique, West Indies. [Bandose, II, 4(5), 4, 4(5)]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 543. In W.T., p. 410, No. 36.

III. Quartz-diorite. Octoraro Ck., Cecil County, Maryland, U.S.A. [Bandose, II, 4, 4, 4]. Anal. W. F. Hillebrand, *Am. Geol.*, xxviii, 1901, p. 146. In W.T., p. 406, No. 2.

It is noteworthy that both the Moyne Farm quartz-mica-diorite and tonalite are comparable with Mont Pélée types.

Column I gives the analysis of the Cox's River type of quartz-mica-diorite.

	I.	Ia.	II.	IIa.
SiO_2	52·43	0·874	53·35	0·889
Al_2O_3	20·11	0·197	18·94	0·186
Fe_2O_3	4·18	0·026	3·71	0·023
FeO	5·59	0·078	5·35	0·075
MgO	4·12	0·103	4·15	0·104
CaO	9·06	0·161	8·50	0·152
Na_2O	2·28	0·037	2·56	0·041
K_2O	0·88	0·010	1·19	0·013
H_2O+	0·36	—	1·13	...
H_2O-	0·16	—	—	—
TiO_2	0·78	0·010	0·93	0·012
P_2O_5	0·32	0·002	—	—
MnO	0·19	0·003	—	—
CO_2	tr.	—	—	—
Total	100·46		99·81	
Sp. Gr.	2·836			

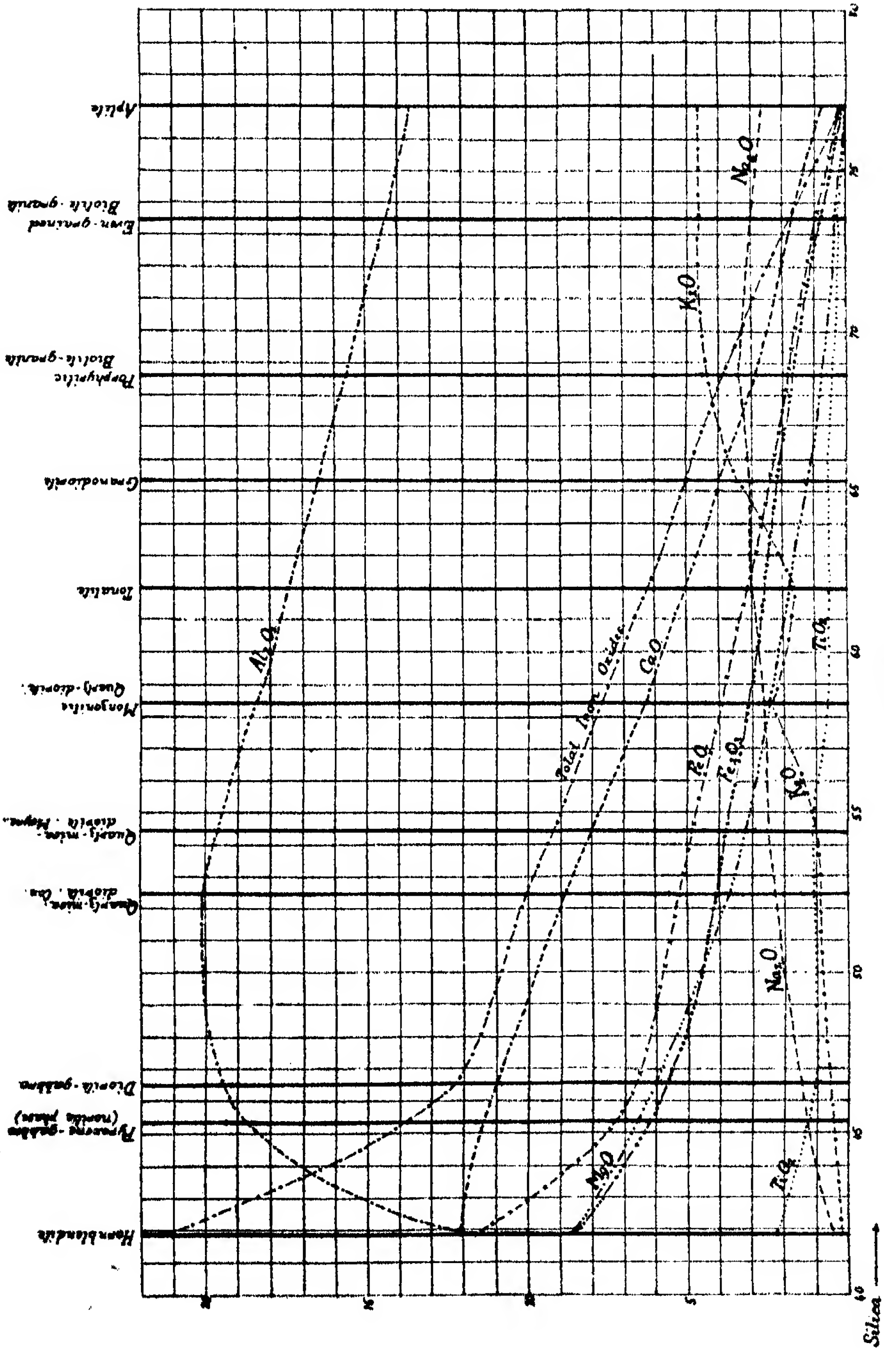
	I.	II.
Quartz	8·34	8·22
Orthoclase	5·56	7·23
Albite	19·39	21·48
Anorthite	41·70	36·70
Diopside	1·11	4·51
Hypersthene	15·71	13·49
Magnetite	6·03	5·34
Ilmenite	1·52	1·82
Apatite	0·67	—

I. Quartz-mica-diorite. Marriott Ck., Cox's River Intrusion, Little Hartley. [Hessose near Bandose, II, (4)5, 4, 4]. Anal. G. A. Joplin.

II. Hypersthene-Basalt. Capo Sperone, San Antioco, Sardinia. [Hessose, II, (4)5, 4, 4]. Anal. A. Johnsen, *Anh. Abh. Pr. Ak. W.*, No. 2, p. 59. In W.T., p. 548, No. 110.

(viii). *Quartz-pyroxene-diorites.*

Three specimens have been collected on Moyne Farm that can be classified neither as quartz-mica-diorites, nor as the more basic diorite-gabbros.


Aplite
Even-grained Biotite-granite
Porphyritic Biotite-granite
Granodiorite
Tonalite
Hornblendite
Diorite-gabbro
Al_2O_3
Total Iron Oxides
CaO
FeO
K_2O
Na_2O
MgO
TiO_2
Silica

Text-fig. 5.

The plagioclase is basic andesine of the composition $Ab_{52}An_{48}$ to $Ab_{56}An_{44}$, and quartz-mica-diorites have been found on the Cox with felspar even more basic than this. The Moyne Farm rocks, however, differ in containing a fair quantity of fresh pyroxene, less biotite, and possibly less quartz.

In the handspecimen they appear to be typical diorites in which plagioclase, hornblende and biotite can be detected; and on account of their general similarity to the quartz-mica-diorites, it is possible that outcrops may have been overlooked, and that these sporadically distributed pyroxene-bearing rocks are more common than they appear to be at present.

Under the microscope the rocks are holocrystalline, hypidiomorphic and ophitic. They consist of plagioclase, hornblende, uralitized and fresh pyroxene (augite and hypersthene), magnetite, quartz, biotite and accessory apatite and rutile. Epidote, sericite, chlorite and lawsonite (?) are possibly deuteric.

As the characters of the individual minerals are essentially the same as those found in the quartz-mica-diorites, a separate detailed description does not seem necessary.

(ix). *Diorite-gabbros.*

This type occurs very abundantly in the Cox's River intrusion, and two outcrops have been met with on Moyne Farm.

On the Cox's River the diorite-gabbros surround the pyroxene-gabbros, and appear to form a reaction rim about them. In the Moyne Farm occurrences, the rock seems to outcrop in isolated masses in the quartz-mica-diorite, and, as is possibly the case with the quartz-pyroxene-diorites, some of these outcrops may have been overlooked.

In the handspecimen, the rock has a typically dioritic appearance and seems to consist of plagioclase and hornblende roughly in equal proportions. The grain-size is medium. Two slightly different types occur in the Cox intrusion, one at the head of Hughes Creek and one about half-way down Marriott's Creek. They are coarse rocks of a fairly light greenish colour, and show a rude banding, the bands being about half an inch wide. These types contain a little more felspar than the normal type, but are otherwise similar.

Under the microscope the rocks are seen to consist of plagioclase, hornblende, iron ores, augite, uralite, secondary sphene, and a little rutile and primary sphene. The plagioclase is slightly dusted with sericite and kaolin. In addition to these minerals, a few of the Cox specimens and one of those from Moyne Farm also contain very small quantities of quartz and biotite. The plagioclase (about 64% of the rock) occurs in stout laths measuring from 0·75 mm. to 2 mm., and is occasionally zoned. It is labradorite ($Ab_{50}An_{50}$ to $Ab_{43}An_{57}$). Hornblende forms subidiomorphic prisms moulding the plagioclase, and is of two varieties. First, a pale-green uralitic variety (about 10%), which is secondary after pyroxene, and is often found surrounding cores of augite and associated with secondary magnetite. Secondly, a deep brownish-green, strongly pleochroic, primary hornblende occurs, and comprises about 22% of the rock. This often fringes the amphibolized pyroxene, though it more frequently forms independent subidiomorphic prisms, which are subophitic towards the felspar. The hornblende is approaching a basaltic variety.

Inclusions of magnetite, ilmenite and apatite are very numerous in the ferro-magnesian minerals, magnetite being particularly well developed (about 4%). The primary mineral forms rudely rectangular grains measuring up to 0·3 mm.,

and contains inclusions of apatite. Magnetite was fairly late in crystallizing, and often moulds plagioclase, and is intergrown with the ferromagnesian constituents.

The pyroxene is almost completely amphibolized, and it would be difficult to say whether it was originally a monoclinic or rhombic variety. Uralite is more abundant than primary hornblende in a few specimens from Cox's River, and the rock stands very close to a pyroxene-gabbro. In those rocks in which there is a little biotite, it is usually at the margins of the uralitized masses. Quartz occasionally forms small interstitial grains, averaging 0·15 mm. in size.

This rock undoubtedly bridges the gap between the diorite and gabbro groups. It is like a diorite in the handspecimen, yet it is a gabbro inasmuch as the plagioclase is labradorite (Iddings, 1909), the chief ferromagnesian mineral was originally pyroxene (Harker, 1919), and the silica percentage is less than 52 (Hatch, 1914). Miss Ida A. Brown has used much the same arguments in justifying the adoption of the same name for a somewhat similar rock at Moruya.

Moreover, in the Cox's River intrusion, field-evidence also points to its being transitional between the diorites and gabbros.

The analysis of the Moyne diorite-gabbro is given below:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	46·49	0·775	47·15	0·786	50·04	0·834
Al_2O_3	19·22	0·188	22·30	0·219	18·68	0·183
Fe_2O_3	0·68	0·042	2·22	0·014	0·80	0·005
FeO	6·02	0·083	6·93	0·096	6·91	0·096
MgO	5·89	0·147	5·15	0·129	7·79	0·195
CaO	10·88	0·195	12·30	0·220	9·88	0·177
Na_2O	2·16	0·035	1·81	0·029	2·35	0·038
K_2O	0·65	0·006	0·35	0·004	0·12	0·001
H_2O+	0·96	—	1·00	—	1·74	—
H_2O-	0·17	—	—	—	0·28	—
TiO_2	0·92	0·011	0·90	0·012	0·80	0·010
P_2O_5	0·40	0·008	0·19	0·001	0·16	0·001
MnO	0·20	0·003	—	—	0·14	0·002
Other Const.	—	—	—	—	0·89	—
Total	100·64		100·30		100·58	
Sp. Gr.	2·967		—		2·977	

	I.	II.	III.
Quartz	0·96	—	0·24
Orthoclase	3·34	2·22	0·56
Albite	18·84	15·20	19·91
Anorthite	40·87	51·71	40·03
Diopside..	8·64	7·72	6·77
Hypersthene	14·93	14·51	27·17
Olivine	—	2·83	—
Magnetite	9·74	3·25	1·16
Ilmenite..	1·67	1·82	1·52
Apatite	1·01	—	0·34

I. Diorite-gabbro. Moyne Farm, Little Hartley. [Hessose, II(III), 5, 4, 4(5)]. Anal. G. A. Joplin.

II. Hornblende-norite. Rivière Clair, Mont Pélée, Martinique, West Indies. [II, 5, 4(5), (4)5]. Anal. A. Pisané, A. Lacroix, Mont Pélée, 1904, p. 543. In W.T., p. 536, No. 64.

III. Diorite. Murgatroyd's Tunnel, New England, N.S.W. [Hessose, II(III), 5, 4, 5]. Anal. J. C. H. Mingaye, *Rec. Geol. Surv. N.S.W.*, viii (3), 1907, p. 216.

(c). Gabbro Group.

(x). *Pyroxene-gabbros.*

These rocks, which vary among themselves in texture, and in the relative importance of some of the mineral constituents, occur abundantly in the centre of the Cox's River intrusion.

The rocks vary from fine-grained, dark massive types, not unlike basalts, to coarse, dark rocks, which may be seen to consist of pyroxene, plagioclase and often hornblende. By an increase in the latter the rock passes into a hornblende-gabbro, and some of the intermediate types show large "shimmer" plates of amphibole, which enclose numerous inclusions, and give both a porphyritic and poikilitic appearance to the rock.

Under the microscope the rock is seen to be holocrystalline, panidiomorphic granular, subophitic and sometimes glomero-porphyritic. The constituent minerals are plagioclase, hypersthene, brown hornblende, augite, iron ores, uralite, sometimes a little biotite, green hornblende, anthophyllite and rutile, and occasionally a tufted amphibole which may be tremolite.

The plagioclase (about 57% of the rock) occurs in laths measuring 1·5–0·5 mm., and these are frequently moulded by pyroxenes and amphiboles. The composition is labradorite and varies from $Ab_{44}An_{56}$ to $Ab_{37}An_{63}$. Some sections show slight zoning. Inclusions of pyroxene and iron ores are often concentrated towards the centre of the crystal, and the felspars show a remarkable clearing, probably indicative of metamorphism (Harker, 1904, and Browne, 1928). It is hoped that the contact metamorphism of these rocks may be studied in the immediate future. Hypersthene varies in abundance in the several types. It is often the most abundant ferromagnesian mineral (24%), but is sometimes subordinate to augite and sometimes to hornblende. It forms subidiomorphic prisms up to 2 mm. in length, and is strongly pleochroic. Crystals often show a fibrous alteration product surrounding them, and sometimes it is found along cracks. The elongation of the fibres is parallel to the "c" axis of the pyroxene. This mineral is colourless, and may be anthophyllite. Around this, there is an outer, very regular rim of a greenish-blue fibrous mineral, and this appears to be of the nature of hornblende. Fine dust, and sometimes small grains, of magnetite are often associated, and in places this has been haematitized. Patches of uralite sometimes occur in the crystals, and may represent one of two things. Either the rhombic pyroxenes may be altering into uralite; or else the uralite may represent original augite, which is sometimes present in parallel intergrowth with the hypersthene.

Brown hornblende forms irregular sheets up to 3·5 mm., which mould the felspars and enclose most of the other minerals. It is usually found surrounding the pyroxenes or uralite. This mineral varies a good deal in abundance, but averages about 6·5%. It is occasionally present only in minute quantities, whilst it increases in amount and finally establishes itself as the chief ferromagnesian

mineral in the hornblende-gabbros. A little green hornblende occurs in some of the more acid types, and this is usually accompanied by biotite. In a few slides the hornblende shows slight zoning as described by Wyllie and Scott (1913), and by Miss Ida A. Brown (1928). Patches of brown hornblende occur in greenish-brown hornblende, and there is a border of a bluish-green variety, which is possibly sodic. Some of the amphibole sections are terminated by small branching tufts, which penetrate the felspar. These may be tremolite. Small veins of amphibole, intersecting all the other minerals, are very numerous.

Augite varies from about 4% to 15% of the rock. In some types it is the main ferromagnesian mineral, whilst in others it is third in order of abundance. It forms subidiomorphic prisms up to 2 mm. across, and groups of these give a glomero-porphyritic fabric in a few sections. Schiller inclusions sometimes occur and the augite is usually somewhat intergrown with hypersthene. Accessory minerals are sometimes present as inclusions. A good deal of the augite is fresh, but those crystals that have suffered alteration have been converted into uralite and secondary magnetite.

Iron ores (about 7%) are usually fresh, and it is difficult to say whether they are ilmenite or magnetite. In consideration of the fact that both occur in other rocks of the series, and that titania is fairly high in the chemical analysis, it is likely that both are present. The crystallization of the primary ore has certainly followed that of plagioclase, and sometimes seems to have been preceded by all except brown hornblende.

The naming of this rock calls for some comment. It has been decided to call the group pyroxene-gabbros for two reasons. Firstly, they all contain both monoclinic and rhombic pyroxene, and this usually exceeds hornblende; secondly, the pyroxenes themselves vary in relative abundance, and many of the types would be classified more correctly as norites. It is desirable, however, that the list of type-names should be kept as low as possible, and as some of the hypersthene may have been produced by contact metamorphism, for the present it seems best to classify both the augite-hypersthene-gabbros, and hypersthene-augite-gabbros as pyroxene-gabbros.

The analysis of the noritic phase is as follows:

SiO_2	45·31	0·755
Al_2O_3	19·39	0·190
Fe_2O_3	5·33	0·033
FeO	7·81	0·108
MgO	6·93	0·173
CaO	11·67	0·209
Na_2O	1·22	0·019
K_2O	0·35	0·003
H_2O+	0·69	—
H_2O-	0·08	—
TiO_2	1·38	0·016
P_2O_5	0·31	0·002
MnO	0·17	0·002
Total	100·59	
Sp. Gr.	3·004	

Quartz	0·96
Orthoclase	1·67
Albite	9·96
Anorthite	46·70
Diopside	7·85
Hypersthene	21·70
Magnetite	7·66
Ilmenite	0·67

Pyroxene-gabbro (Norite). Cox's River, Por. 27, Parish of Lowther. [Kedabekase, III, 5(4), 5, 4(5)]. Anal. G. A. Joplin.

(xi). *Hornblende-gabbros.*

These rocks occur in isolated outcrops among the pyroxene-gabbros, and seem to grade into the pyroxene-bearing types. It is possible that these masses may represent cognate xenoliths, which have been caught up in the pyroxene-gabbro magma whilst they were still hot and only partly consolidated. The hornblende gabbros are usually coarse-grained, dark rocks, which appear to consist of hornblende and plagioclase. In some types the plagioclase is not abundant and the rock stands very close to a hornblendite.

Under the microscope the rock is seen to be holocrystalline, hypidiomorphic-granular and ophitic. The chief constituent minerals are brown hornblende, plagioclase, uralitized pyroxene, iron ore and apatite. In one slide a little green hornblende is present, and the plagioclases are usually dusted with a little sericite and kaolin.

The plagioclase (about 33·5% of the rock) is basic labradorite ($Ab_{32}An_{68}$ to $Ab_{37}An_{63}$), and occurs in stout laths which average 2 mm. in length. Albite, and sometimes pericline, twinning is well developed and a slight alteration is usually evinced by a dusting of sericite and kaolin. Sometimes, however, the plagioclase shows clearing. The plagioclase is moulded by hornblende. Brown hornblende forms large subidiomorphic crystals up to 4 mm. across. These mould the felspars, and partly enclose all the other minerals. A slight zoning is apparent, and veins of green amphibole cut through the rock. The fibres of these veins are parallel, and apparently continuous with the amphiboles that the veins intersect. This mineral comprises about 41% of the rock. A little fresh augite is sometimes present, and uralitized masses of pyroxene quite abundant (about 19%). These pseudomorphs form subidiomorphic columnar sections about 2 mm. in length, and in places tufts or sheaves of pale-green amphibole appear to terminate the pseudomorphs and penetrate adjacent felspars. Secondary magnetite is commonly associated with the uralite. Primary magnetite is moderately well developed in most sections and averages about 6·5%. A little apatite is usually present.

(xii). *Hornblendite.*

This rock appears to occur in irregular small masses in both pyroxene-gabbros and hornblende-gabbros. The masses are sometimes somewhat ovoid and measure a couple of inches across, but at other times they have more the appearance of veins. Some of the inclusions are most irregular in shape, and are possibly basic segregations. They seem to occur more frequently, however, as small cognate xenoliths which have been caught up whilst the magma was still hot. The vein-like appearance is possibly due to a string of these inclusions being drawn out in a certain direction whilst they were still hot and plastic.

In the handspecimen the hornblendites appear to consist of fairly large, black hornblende crystals, but, under the microscope, they are seen to be composed of brown hornblende, iron ores, plagioclase, apatite, uralite and a little quartz, actinolite, calcite, and possibly tremolite.

Brown hornblende (about 54·5% of the rock) forms large subidiomorphic prisms up to 5 mm. across, and wraps the plagioclase. It includes the accessory minerals, and in one place is seen to enclose a mass of calcite, epidote and small grains of felspar and quartz. This mass evidently represents a pseudomorph of some inclusion mineral, but it is impossible to say what the original mineral may have been. The hornblende shows zoning, a bright-green border being present on the outer edges, and also around large inclusions. A good deal of uralite is present (about 5·5%) and sometimes tufts and sheaves of a fibrous amphibole penetrate quartz and felspar. Some of this is pale-green and some colourless, and it would thus seem likely that some has affinities towards actinolite, and some towards tremolite. The iron ores occur in large, somewhat rectangular grains up to 0·75 mm. Some skeleton grains occur, and these may represent ilmenite. These ores comprise some 15% of the rock. Plagioclase (some 12%) is andesine ($Ab_{68}An_{32}$), and most of it is rather altered into kaolin and sericite. Some, however, appears to be quite fresh. A kind of mesostasis is present (about 12%) and this is made up of altered plagioclase, masses of uralitized pyroxene, sheaved and tufted amphiboles, epidote, calcite and some quartz grains.

This rock is certainly an irregular type, but appears to agree fairly closely in mineral composition with one that has been described as a davainite by Wyllie and Scott (1913) from Garabal Hill, Scotland. These workers have noted brown hornblende, much of which is secondary after pyroxene, and andesine as the main constituents of the davainite, but no reference is made to quartz, which appears in the Hartley type. The analysis of the davainite is given for comparison and certain similarities are apparent.

The low specific gravity and the occurrence of relatively acid felspar and quartz would seem to imply that the Hartley rock is a hybrid or has suffered metamorphism.

The analysis of the Hartley rock is given in Column I:

	I.	Ia.	II.	IIa.	III.	IIIa.
SiO_2	41·82	0·697	40·2	0·670	43·53	0·726
Al_2O_3	11·79	0·116	9·5	0·093	7·24	0·071
Fe_2O_3	8·64	0·054	9·7	0·060	11·10	0·069
FeO	11·68	0·163	12·2	0·170	8·70	0·121
MgO	8·68	0·217	8·0	0·200	11·51	0·288
CaO	12·14	0·214	13·1	0·234	10·19	0·182
Na_2O	0·53	0·008	0·8	0·013	2·88	0·047
K_2O	0·25	0·003	0·2	0·002	1·39	0·015
H_2O+	0·47	—	0·5	—	1·34	—
H_2O-	0·16	—	—	—	0·43	—
TiO_2	2·26	0·029	4·7	0·059	1·90	0·024
P_2O_5	0·42	0·003	—	—	tr.	—
MnO	0·20	0·003	0·4	0·006	—	—
CO_2	0·53	—	..	—	abs.	—
FeS_2	—	—	0·4	—	—	—
Total	99·55		99·7		100·21	
Sp. Gr.	3·000		3·36			

	I.	II.	III.
Quartz	1·26	0·66	—
Orthoclase	1·67	1·11	8·34
Albite	4·19	6·81	13·62
Anorthite	29·19	21·68	8·06
Nepheline	...	—	5·96
Diopside	22·50	34·79	37·42
Hypersthene	21·76	10·84	—
Olivine	—	—	10·57
Magnetite	12·53	13·92	16·01
Ilmenite	4·41	8·97	3·65
Apatite	1·01	—	—

I. Hornblendite. Cox's River, Por. 27, Parish of Lowther. ["IV, 2, 1, 2, "3]. Anal. G. A. Joplin.

II. Gabbro. Druin an Eidhne, Skye, Scotland. [IV, 2", 1, 2, 3]. Anal. J. H. Player, *Q.J.G.S.*, l, 1894, p. 653. In W.T., p. 716, No. 1.

III. Davainite (Hornblendite). Garabal Hill, nr. Loch Lomond, Scotland. [Montrealose, "IV, 2, 2, 2, 2]. Wyllie and Scott, *Geol. Mag.*, (v) x, 1913, p. 502. In W.T., p. 718, No. 5.

II. *Hypabyssal Types.*

(1). Pegmatites and Aplites.

(i). *Pegmatites and Micropegmatites.*

A dyke of coarse, decomposed pegmatite occurs on the Jenolan Road to the north of the Glenroy Bridge. It is creamy-white in colour, and its structure is somewhat suggestive of the Cooma pegmatites, a graphic intergrowth of orthoclase and quartz forming the outer portion of the dyke, and a quartz vein the centre. A somewhat similar occurrence is met with on Williams' property at the head of Moyne Creek. The exposure is only a small one, but it is possibly continuous with a pegmatite and acid granite on Bonnie Blink. These are probably outcrops of an apophysis from the granite to the west.

Small veins of pink pegmatite and micropegmatite are numerous among the acid granites around the village of Hartley, and quite a striking set of micropegmatite veins is found cutting through an outcrop of quartz-mica-diorite near the mouth of Kanimbla Creek. This rock has been sectioned and found to consist of quartz, orthoclase, microperthite, a little plagioclase ($Ab_{75}An_{25}$), and a small amount of biotite, magnetite and lawsonite (?). A micrographic fabric is perfectly developed and the grainsize is 1·3 mm.

(ii). *Aplites.*

Granite-aplites occur abundantly, both as dykes several feet in width and as veins and veinlets that are often mere threads and can only be distinguished under the microscope. Aplites intrude both acid and intermediate types, but none has been observed in association with any rock more basic than the quartz-mica-diorites, and it appears that the intermediate types are affected only by the smaller vein intrusions.

On the Jenolan Road, about midway between the bridges, a dyke of aplite about 2 feet in width follows a prominent line of jointing in the granite, and strikes N 10° W. Several such dykes are found to follow major joint-directions on the northern bank of the River Lett, behind the Court House. A fairly large outcrop of aplite occurs among the granites on Campbell's Creek, and though its mode of occurrence has not been ascertained, it is possibly a large dyke.

On Moyne Farm the tonalites are often threaded by small aplite veins, which rarely exceed half an inch in width. Like the quartz veins, to which reference has been made, there appear to have been two periods of aplitic injection. Some of the veins are well defined, and under the microscope show chilled borders, whilst others have obviously been injected into a hot, and only partly solidified, rock, and the local monzonitic fabric which has already been referred to has been produced.

The aplites vary in grainsize from 1 mm. to 0·1 mm., and in some of the coarser types there is a slight graphic intergrowth of quartz and orthoclase. A kind of monzonitic fabric is sometimes produced by the late consolidation of the orthoclase.

The rocks consist of a mosaic of quartz and orthoclase or microperthite, plagioclase and a little biotite, magnetite and ilmenite. In a few slides apatite and secondary sphene have been noted. The plagioclase is acid oligoclase of the composition $Ab_{89}An_{11}$. Biotite is usually bleached, often chloritized and sometimes contains lenses of lawsonite (?).

Some of the aplites have suffered a certain amount of pneumatolysis, as evidenced by the occurrence of small quantities of molybdenite, cassiterite, fluorspar, and tourmaline. Some of the aplites show greisenization, but these have not been studied in detail.

The analysis of the rock from Campbell's Creek is given in Column I:

	I	Ia.	II.	IIa.	III.	IIIa.
SiO_2	76·94	1·282	76·90	1·282	75·67	1·261
Al_2O_3	13·98	0·137	12·53	0·123	13·74	0·134
Fe_2O_3	0·18	0·001	0·99	0·006	0·67	0·004
FeO	0·27	0·004	0·66	0·009	0·72	0·010
MgO	0·06	0·001	0·17	0·004	0·25	0·006
CaO	0·78	0·014	0·86	0·015	0·90	0·016
Na_2O	2·68	0·044	2·36	0·038	2·60	0·042
K_2O	4·67	0·050	4·92	0·052	4·85	0·052
H_2O+	0·39	—	0·43	—	0·64	—
H_2O-	0·11	—	—	—	—	—
TiO_2	0·16	0·003	0·50	0·006	0·29	0·004
P_2O_5	0·02	—	—	—	—	—
MnO	tr.	—	0·08	0·001	none	—
Total	100·24		100·40		100·33	
Sp. Gr.	2·603					

	I.	II.	III.
Quartz ..	41·34	42·48	39·42
Orthoclase	27·80	28·91	28·91
Albite ..	23·06	19·91	22·01
Anorthite	3·89	4·17	4·45
Corundum	2·96	1·84	2·55
Hypersthene	0·20	0·40	0·86
Magnetite	0·23	0·93	0·93
Ilmenite..	0·46	0·91	0·61
Haematite	—	0·32	—

I. Aplite. Campbell's Creek, Little Hartley. [Tehamose, I, 3", (1)2, 3]. Anal. G. A. Joplin.

II. Granite. Grafversfors, Stofsjö, Sweden. [Tehamose, I, 3", (1)2, "3]. Anal. H. Santesson. P. J. Holmquist, *B. Un. Ups.*, vii, 1906, p. 264. In W.T., p. 82, No. 31.

III. Granite. Örnsköldsvik, Angermanland, Sweden. [Tehamose, I, 3", (1)2, 3]. Anal. H. Santesson. P. J. Holmquist, *B. Un. Ups.*, vii, 1906, p. 260. In W.T., p. 82, No. 34.

(2). Granite Porphyry.

Collinear outcrops of granite-porphyry occur in Portions 172, 173, 175 and 183, Parish of Hartley, and form a small chain of low hills across Moyne Farm. Though no intrusive relations have been observed between this rock and the tonalites and quartz-mica-diorites with which it is associated, the collinear arrangement of the outcrops would suggest a large contemporaneous apophysis of the granite.

The rock is of a pink colour, and there is a decided variation in texture. Though the microscope reveals a porphyritic structure in every case, many of the handspecimens appear to be even-grained, fairly coarse biotite-granites. In the handspecimens of the obviously porphyritic types, phenocrysts of plagioclase, quartz and a little biotite are set in a dull pink lithoidal groundmass. The phenocrysts vary considerably in size and perfection of development. One outcrop on Moyne Creek contains perfect, tabular plagioclases, 20 × 10 mm.

Under the microscope the granite porphyries are seen to consist of plagioclase, quartz, biotite and occasional orthoclase phenocrysts set in a holocrystalline mosaic of quartz, orthoclase and a little biotite. In a few slides a small quantity of plagioclase has also been detected in the groundmass. The grainsize is very variable. The phenocrysts usually average from 3 mm. to 6 mm., and the groundmass, which is always holocrystalline, is fine to medium, and ranges from 0·05 mm. to 0·5 mm.

The plagioclase, forming subidiomorphic tabular phenocrysts, is oligoclase ($Ab_{71}An_{29}$ to $Ab_{69}An_{31}$), and is both kaolinized and sericitized. In one slide bunches of secondary muscovite form small, radiating fans in the felspar. Occasionally zoning is present, and in such cases alteration is selective. Quartz is developed both as subidiomorphic and allotriomorphic phenocrysts, and as irregular grains, which are very abundant in the groundmass. Most of the phenocrysts show corrosion and in some cases pseudo-inclusions are developed. Granulation and undulose extinction are sometimes present. One slide shows a corroded and "nibbled" subidiomorphic phenocryst bordered by smaller quartz grains, which

appear to be a graphic intergrowth with the felspar of the groundmass. Harker and Marr (1891), Kemp (1922) and Miss Ida A. Brown (1928) have observed similar structures. Orthoclase (usually microperthite) is very well developed as small grains in the groundmass, but only in a few cases has it been observed as phenocrysts.

A granite-porphyry collected on the Bathurst Road to the east of McGarry's Hotel, however, contains phenocrysts of this mineral. This rock has not been observed *in situ*, but may represent a marginal phase of the biotite-granite. This possibility will be referred to later.

Biotite is developed in tabular flakes as phenocrysts which measure up to 2 mm. across, but is more frequently found as scattered shreds in the groundmass. This mineral has suffered considerable alteration. Apatite often occurs as inclusions, and one large section, measuring 0·3 mm., has been observed. Sphene is also a common accessory. Epidote is abundant as an alteration product, and in one slide a large crystal of allanite has been noted. Iron ores are accessory and comprise both magnetite and ilmenite, and alteration products are represented by chlorite, epidote, haematite and carbonates.

Unfortunately all the specimens that have been sectioned (18) have suffered a certain amount of decomposition by weathering, but in many of the slides the amount of alteration does not warrant the assumption that all has been produced by weathering alone, and there seems little doubt that magmatic solutions have played a part. Quartz phenocrysts are corroded and exhibit pseudo-inclusions, felspars are sericitized and kaolinized, but it is the biotite that produces the strongest evidence of a deuteric period.

In the less altered rocks the biotite is bleached, and secondary magnetite now converted into haematite, possibly by weathering, has been thrown out along cleavage planes. Chlorite and epidote are also present and quartz and felspar grains are associated. In one slide a phenocryst of biotite is entirely replaced by chlorite, in which there are parallel strings of magnetite and haematite grains, and associated granules of epidote.

A further advance in the alteration is shown by masses of chlorite, haematite and epidote up to 3 mm. across. These appear to be pseudomorphs after clusters of biotite flakes. They contain parallel bands of secondary magnetite grains, which indicate the orientation of the original biotites.

Another slide shows a still more advanced stage, but in this case it is likely that surface weathering has played a part. In this rock, "ghosts" of biotite are represented by masses of fairly regularly arranged strings of magnetite and haematite grains with interleaved grains of quartz, felspar, epidote and carbonates.

There appear to have been two main deuteric processes operating upon the biotite: (1) Chloritization, (2) epidotization. It is not possible to trace each whole process through a series of slides, since both operate together, and often interfere with one another. Both processes have caused the throwing out of secondary magnetite, and at times silica has been set free as quartz. Orthoclase is also produced in an advanced stage of the breaking down of the biotite.

From an examination of these slides, it has been inferred that "secondary" minerals have been produced chiefly by deuteric action, but in some of the more altered types weathering has undoubtedly played a part.

Deuteric: (1) *Epidotization;* (2) *chloritization;* (3) *some oxidation;* (4) some carbonation.

Weathering: (1) Most of the oxidation, i.e., haematite, etc.; (2) most of the carbonation.

(3). Hornblende-Lamprophyres.

These rocks have not been found *in situ*, but occur as boulders in the Cox's River in the immediate vicinity of the gabbro intrusion, and it is likely that this is an associated type. The name lamprophyre is applied only tentatively until something of the field occurrence is known. The rocks are not lamprophyres in the strict sense of the word, for felspar is just as abundant as ferromagnesian minerals. In the handspecimen the rocks are light-grey in colour with large phenocrysts of dark blackish-green hornblende up to 10 mm. across.

Under the microscope the phenocrysts are seen to be large idiomorphic or subidiomorphic crystals of amphibolized pyroxene fringed by biotites and iron ore; or groups of these minerals that give a porphyritic effect. The groundmass consists of a plexus of plagioclase laths and interstitial quartz.

III. *Inclusions and Segregations.*

Very little work has been done on these occurrences, and little can be said about them here.

Inclusions are of two classes—those of sedimentary, and those of igneous origin.

The sedimentary type are very numerous near the contact zones, and are often up to a foot across. Some of these occur among the granites on Grant's Creek, and a kind of "swirling" structure shows that the inclusion has been rendered plastic by the great heat of the magma in which it became engulfed.

The igneous inclusions are very common throughout the series, but are most abundant in the intermediate types.

On the property of Mr. J. Commens weathering of the hornblende-biotite-granite has caused the finer-grained inclusion to stand out in small knobs. Small inclusions are also numerous among the porphyritic granites at Hartley, and among the granodiorites at the mouth of Campbell's Creek. One of the latter has been sectioned and certainly appears to be a rather abnormal type. The best name that can be applied to it is a sphene-quartz-diorite.

It has already been indicated that the hornblendite probably occurs as cognate xenoliths, and there is some slight suggestion of their being basic segregations.

D. PETROGENY.

(a). *The "Reaction Principle".*

The foregoing descriptions servo to indicate that there are some striking examples of Bowen's "reaction principle" among the Hartley rocks (Bowen, 1922).

Not only does the series as a whole illustrate this phenomenon, but often much is to be seen within a single specimen.

Some of the basic rocks show an association of hypersthene, augite, brown hornblende and biotite; and thus exemplify an almost complete "discontinuous reaction" series as outlined by Bowen (1922). A "continuous reaction" series is exemplified by the zoning in the hornblende, which in some cases shows a brown centre, a green hornblende zone, and a bluish-green sodic border. The best example of this type of series is shown by the plagioclase. Zoning may be seen in individual slides, but taking the series as a whole there is an increase in the acidity of the felspar from $Ab_{32}An_{68}$ to $Ab_{89}An_{11}$.

Other examples of the operation of the reaction principle amongst New South Wales rocks have been described by Miss Ida A. Brown (1928) from Moruya, and by Dr. W. R. Browne and Mr. W. A. Greig (1923) from Kiandra. Dr. Browne has also described quartz-dolerites from Adélie Land, Antarctica, which exemplify this principle.

Such a mineral association gives some indication of the conditions under which the magma cooled, but this will be discussed later under differentiation.

The mineral content of thirteen of the types described has been tabulated in such a way as to give the same picture as that conveyed by Bowen's diagram (1922).

	Rhombic Pyroxene.	Monoclinic Pyroxene.	Brown Hornblende.	Green Hornblende.	Biotite.	Quartz.	Orthoclase.	Acid Oligoclase.	Basic Oligoclase.	Acid Andesine.	Basic Andesine.	Acid Labradorite.	Basic Labradorite.
Hornblende-gabbro ..	×	×	×	.									×
Pyroxene-gabbro ..	×	×	×	.								×	
Diorite-gabbro		×	×	×								×	
Qtz.-pyrox.-diorite ..		×	×	×	×	×					×		
Qtz.-mica-diorite.. ..			.	×	×	×					×		
Monz.-qtz.-diorite ..				×	×	×	×			×			
Tonalite				×	×	×	.			×			
Granodiorite				×	×	×	×			×			
Hb.-bi.-Granite				×	×	×	×		×				
Porph.-bi.-Granite ..					×	×	×		×				
Biotite-granite					×	×	×		×				
Granite-porphyry ..					×	×	×	×					
Aplite					.	×	×	×					

Diagram to show mineral constituents of the type rocks at Hartley.

(b). *Deuteric Action.*

There seems little doubt that the Hartley rocks have suffered a certain amount of deuteric action. The chief deuteric minerals that have been recognized are lime- and potash-bearing types. Sodic minerals seem to be entirely absent.

No hard and fast line can be drawn between the periods at which the "reaction principle" ceases to operate and deuteric phenomena begin. Both processes are destructive and constructive, and it is possible that the formation of sodic hornblende may be of deuteric origin. Some of the rocks that have been analysed have suffered a certain amount of deuteric alteration, yet there is no marked deviation apparent in the variation diagram, so it is concluded that there has been a re-assemblage of minerals, rather than that additive or subtractive processes have been at work.

A glance at the chemical analyses (p. 53), and at the variation diagram (Text-fig. 5), will show that ferric iron is unusually high. Total iron is certainly high throughout the series, but in normal fresh rocks it is not usual for ferrous and ferric iron to be about equal amount, which is the case with most of the Hartley types. It is concluded from this, that oxidation of ferrous iron has taken place as a result of deuteric action.

(c). *Chemical Discussion.*

Eleven chemical analyses have been made of the chief rock types, and these amply confirm the other evidence of consanguinity. Not only is this close relationship borne out by the analyses, but reference to the norms (p. 53) will show also that there is a gradation in class, order, rang, and subrang.

A variation diagram has been plotted according to Harker's method, and the curves have been somewhat smoothed, though no very wide deviation of the curves has been necessary. In some cases, points actually coincide with the plotted curves. This method of representation has been useful in comparing the rocks of two other series that have been similarly plotted; namely, the Garabal Hill complex, Scotland, and the Moruya complex, N.S.W. The similarity in all three instances is quite striking, and the features of the complexes suggest serial differentiation in a subalkaline or calcic magma. With regard to the Moruya series, Miss Brown says: "the relatively sudden change in the amount of curvature of the oxide-curves between the diorite-gabbro and the more basic gabbro is suggestive of complementary, as opposed to serial differentiation. This idea is supported by the field-occurrence of the hornblende-gabbro."

It is likely that the same explanation might hold for the sudden change of curvature between the pyroxene-gabbro and hornblendite at Hartley. The mode of occurrence here also is suggestive of complementary differentiation.

There is one very marked difference between the Moruya and Garabal Hill complexes on the one hand, and the Hartley series on the other. In the former, magnesia is a very abundant constituent towards the basic end of the series, and greatly exceeds ferrous oxide, with which it is replaceable. At Hartley, however, ferrous oxide is always present in greater quantity, and magnesia does not approach it even in the ultrabasic type.

Another striking feature of the Hartley series is the abundance of ferric oxide, which is usually about equal to ferrous oxide. As already stated, this can possibly be accounted for by deuteric action and "reaction", since many of

the slides show a good deal of secondary magnetite, which is evidently due to the oxidation of the ferrous oxide contained in the ferromagnesian minerals.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
SiO_2 ..	41·82	45·31	46·49	52·41	54·37	58·37	62·06	65·33	68·60	73·51	76·94
Al_2O_3 ..	11·70	19·30	19·22	20·11	19·64	18·38	18·25	16·20	15·33	14·03	13·98
Fe_2O_3 ..	8·64	5·38	6·68	4·18	4·30	2·80	2·91	2·43	1·92	0·69	0·18
FeO ..	11·68	7·81	6·02	5·59	4·87	4·43	2·94	2·38	1·85	0·91	0·27
MgO ..	8·68	6·98	5·89	4·12	2·94	2·79	1·71	1·28	0·81	0·38	0·06
CaO ..	12·14	11·67	10·88	9·06	8·07	6·29	4·90	4·02	2·78	1·69	0·78
Na_2O ..	0·53	1·22	2·16	2·28	2·55	2·52	3·12	3·02	3·38	3·03	2·68
K_2O ..	0·25	0·35	0·65	0·88	1·01	2·56	1·61	3·28	4·52	4·58	4·67
H_2O+ ..	0·47	0·69	0·96	0·36	0·96	0·56	1·34	0·58	0·50	0·20	0·39
H_2O- ..	0·16	0·08	0·17	0·16	0·11	0·16	0·16	0·10	0·11	0·18	0·11
TiO_2 ..	2·26	1·33	0·92	0·78	1·14	0·52	0·60	0·72	0·51	0·45	0·16
P_2O_5 ..	0·42	0·31	0·43	0·32	0·34	0·26	0·24	0·22	0·22	0·05	0·02
MnO ..	0·20	0·17	0·20	0·19	0·07	0·06	0·09	0·03	0·04	0·01	tr.
CO_2 ..	0·53	tr.	tr.	tr.	—	—	—	—	—	—	—
Total ..	99·55	100·59	100·64	100·46	100·37	99·70	99·93	99·59	100·57	99·81	100·24
Sp. Gr. ..	3·000	3·004	2·967	2·836	2·861	2·807	2·764	2·742	2·703	2·658	2·603

	I.	II.	III.	IV.	V	VI.	VII.	VIII.	IX.	X.	XI.
Quartz ..	1·26	0·96	0·96	8·34	13·14	14·76	24·12	24·78	24·18	34·68	41·34
Orthoclase ..	1·67	1·67	3·34	5·56	6·12	15·57	9·45	19·46	26·69	27·24	27·80
Albite ..	4·19	9·96	18·34	19·39	20·96	20·96	26·20	25·15	28·82	25·15	23·06
Anorthite ..	29·19	46·70	40·87	41·70	38·09	29·47	23·63	18·90	13·07	8·34	3·89
Corundum ..	—	—	—	—	0·41	0·20	2·65	0·82	—	1·33	2·96
Diopside ..	22·50	7·85	8·64	1·11	—	—	—	—	—	—	—
Hypersthene	21·76	21·70	14·93	15·71	11·00	11·02	6·28	4·39	3·06	1·16	0·20
Magnetite ..	12·53	7·66	9·74	6·03	6·26	4·18	4·18	3·48	2·78	1·16	0·23
Ilmenite ..	4·41	2·43	1·67	1·52	2·13	0·91	1·22	1·37	0·91	0·91	0·46
Apatite ..	1·01	0·67	1·01	0·67	0·67	0·67	0·34	0·34	0·34	—	—
Class ..	"IV	III	II (III)	II	II	"II	I (II)	I (II)	I"	I	I
Order ..	2	5 (4)	5	(4) 5	4"	4"	4	4	4	(3) 4	3"
Section ..	'1	—	—	—	—	—	—	—	—	—	—
Rang ..	2	5	4	4	4	3 (4)	3	3	2"	2	(1) 2
Sub-rang ..	"3	4 (5)	4 (5)	4	4	3"	4	3"	3	3	3
Magmatic Name.	Yamaskase.	Kedabekase.	Hessose.	Hessose near Bandose.	Bandose.	Harzose near Bandose.	Yellowstonose near Tonalose.	Amiatose near Harzose.	Toscanose.	Toscanose near Tehamose.	Tehamose.

I. *Hornblendite. Cox's River, Por. 27, Parish of Lowther.*
II. Pyroxene-gabbro (Norite). Cox's River, Por. 27, Parish of Lowther.
III. Diorite-gabbro. Moyne Farm, Little Hartley.
IV. Quartz-mica-diorite. Marriott Ck., Cox's River intrusion.
V. Quartz-mica-diorite. Moyne Farm, Little Hartley.
VI. Monzonitic Quartz-diorite. Kanimbla Station, Little Hartley.
VII. Tonalite. Moyne Farm, Little Hartley.
VIII. Granodiorite. Junction of Campbell's Ck. and Cox's River, Hartley.
IX. Porphyritic Biotite-granite. Bathurst Road, Por. 4, Parish of Hartley.
X. *Even-grained Biotite-granite.* Bathurst Road, Por. 4, Parish of Hartley.
XI. Aplite. Campbell's Creek, Hartley.

Table of Specific Gravities.

Name of Type.	No.	Sp. Gr.	Remarks.
Granite-porphyry..	A.32	2·597	Slightly weathered.
,, ,, ...	A.12	2·657	
Aplite	D.40	2·603	
Even-grained biotite-granite ..	D.22	2·608	Slightly weathered.
,, ,, ,, ,, ..	D.63	2·658	
,, ,, ,, ,, ..	D.25	2·688	
Porphyritic biotite-granite ..	D.20	2·703	
Hornblende-biotite-granite ..	D.30	2·705	
,, ,, ,, ..	D.33	2·706	
,, ,, ,, ..	D.39	2·706	
Granodiorite	D.1	2·742	
Tonalite	A.20	2·742	
,, ...	A.14	2·764	
Monzonitic quartz-diorite ..	D.16	2·807	
Quartz-mica-diorite	A.36	2·750	Rather weathered.
,, ,, ,, ...	A.37	2·754	,, ,,
,, ,, ,, ...	A.53	2·849	
,, ,, ,, ...	A.65	2·854	
,, ,, ,, ...	A.11	2·861	
,, ,, ,, ...	B.102	2·863	
,, ,, ,, ...	B.95	2·883	
,, ,, ,, ...	B.79	2·894	
,, ,, ,, ...	B.90	2·898	
,, ,, ,, ...	B.114	2·900	
,, ,, ,, ...	A.50	2·923	
Quartz-pyroxene-diorite.. ..	A.9	2·990	High on account of small segregation.
Diorite-gabbro	B.93	2·917	
,, ,, ...	B.108	2·963	
,, ,, ...	A.33	2·967	
Pyroxene-gabbro	B.26	2·960	
,, ,, ...	B.10	3·004	
,, ,, ...	B.30	3·018	
Hornblende-gabbro	B.40	3·036	
Hornblendite	B.24	3·000	Possibly low on account of small piece used.

The presence of normative quartz, even in the basic types, may possibly be accounted for by this oxidation of the ferrous iron. Free quartz is certainly present in the hornblendite, but the normative figure would exceed the modal. It has been suggested (Browne and White, 1929) that high Fe_2O_3 necessitates the using up of a good deal of FeO for the formation of magnetite in the norm. This leaves a deficiency of FeO for the femic minerals, and the SiO_2, which would have entered into their composition, comes out in the norm as free quartz.

The relatively high alumina content of the Hartley rocks can possibly be explained by the abundance of biotite, which is an essential constituent of all types between the biotite-granite and the quartz-pyroxene-diorite. It has also been found as an accessory in the aplite, and in the more basic types.

Soda is fairly high, particularly towards the more acid end of the series, and this is probably due in part to the presence of albite in the microperthite in the acid and intermediate-acid types.

As in other rocks of comparable age in the State, titania is an important constituent. In the ultrabasic rocks this oxide exceeds the sum of the alkalis, and in the aplite it is comparable in amount to the ferromagnesian constituents.

(d). *Possible Differentiation of the Bathylithic Rocks.*

The fact that the Hartley outcrops represent only small portions of a large intrusion puts many difficulties in the way of a discussion on the differentiation. It is desirable, therefore, to tabulate the following field observations:

(1) A gradation between the types on Moyne Farm.
(2) A gradation between the rocks in the Cox's River intrusion.
(3) An apparent gradation between most of the other types at Hartley.
(4) A normal sequence from basic margin to acid centre on Moyne.
(5) An abnormal sequence from acid margin to basic centre on the Cox's River and River Lett.
(6) Contemporaneous acid dykes, apophyses and veins.
(7) Later dykes and veins that present chilled margins.
(8) The occurrence of basic cognate xenoliths both large and small.

More detailed observations of the stocks have led to the establishment of the following facts:

Cox's River Intrusion.

(1) A margin of quartz-mica-diorite,
(2) which grades into diorite-gabbro,
(3) which surrounds a central mass of pyroxene-gabbro,
(4) which includes sporadically distributed hornblende-gabbros and hornblendite.

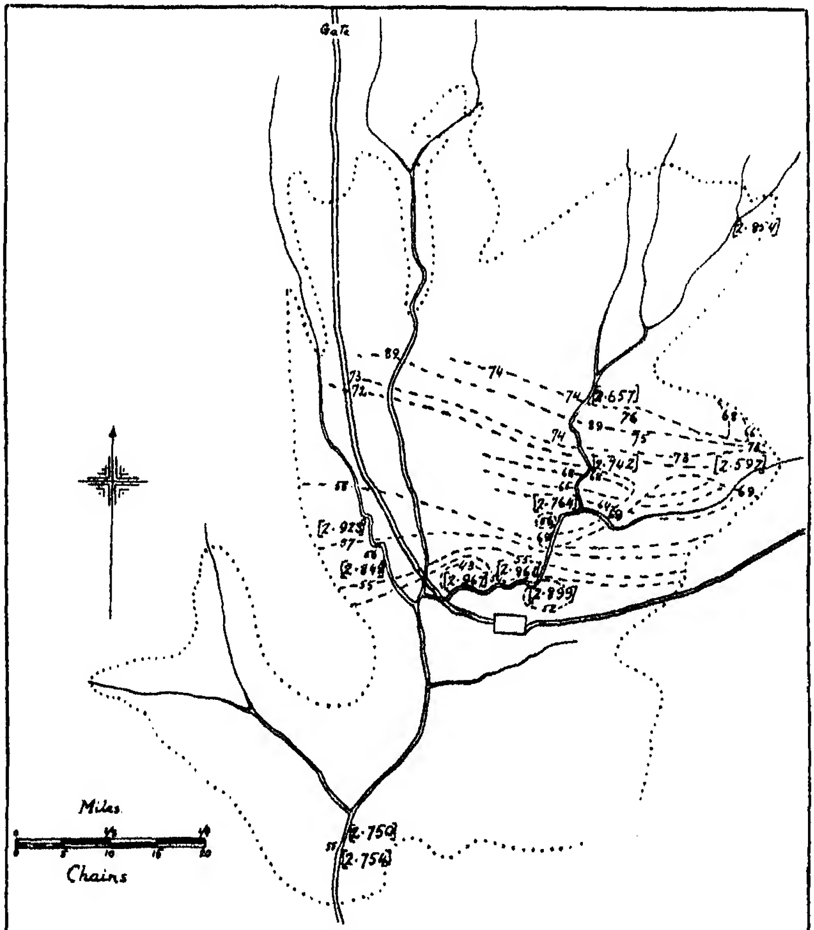
Moyne Farm Intrusion.

(1) A margin of fine-grained quartz-mica-diorite,
(2) which passes into normal quartz-mica-diorite,
(3) which grades into a central mass of tonalite.
(4) Both the quartz-mica-diorite and tonalite contain xenoliths of quartz-pyroxene-diorite and diorite-gabbro.
(5) An apophysis of granite-porphyry and small aplite veins are contemporaneous.
(6) Other veins of aplite and quartz are later.

The chemical and petrographical work points to undoubted consanguinity among the fifteen types that have been described in this paper, and it is evident that all were derived from one original magma.

The Cox's River intrusion appears to be due to two injections of partial magma, (1) a basic one with ultrabasic inclusions, and (2) a quartz-mica-diorite one which reacted with the gabbro to form a diorite-gabbro.

The Moyne Farm intrusion is apparently due to the differentiation in place of a partial dioritic magma, which contained inclusions of gabbros, and reacted with



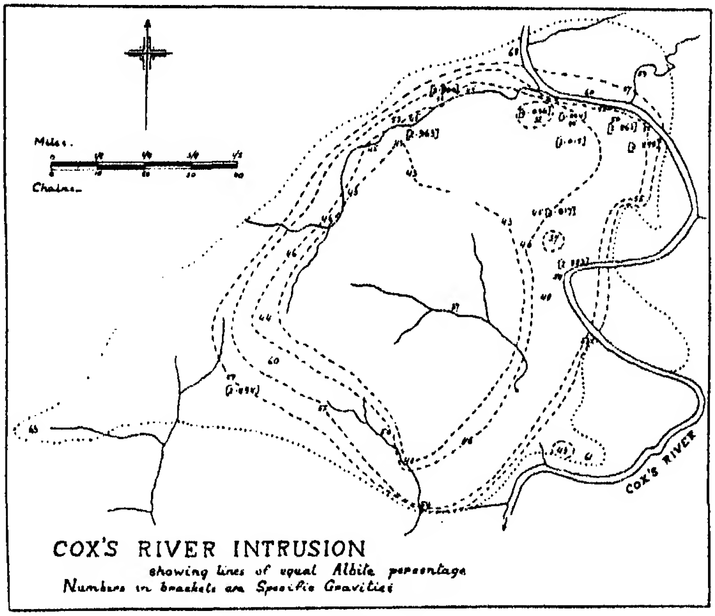
MOYNE FARM INTRUSION
showing lines of equal Albite percentage
Numbers in brackets are Specific Gravities

Text-fig. 6.

them to form slightly more acid types. The fine-grained phase of the quartz-mica-diorite represents the quickly cooled rock at the contact, and this possibly formed a non-conducting envelope, and differentiation in place thereby proceeded more slowly. The steep temperature gradient would cause convection currents to be set up, and as the more basic constituents consolidated about the margin, the currents would carry the more basic ingredients from the centre, and so cause a gradation into a more acid facies.

Reference to the maps (Text-figs. 6, 7) shows that the specific gravities and the composition of the felspars are in accord with this hypothesis of differentiation.

The injection of the main acid bathylith evidently followed that of the quartz-mica-diorite, before the latter was completely cooled. The granite-porphyry on Moyne Farm is apparently an apophysis of the granite, but is more or less contemporaneous with the diorites.



Text-fig. 7.

The first period of aplitic injection, on Moyne Farm, possibly accompanied this apophysis, and the second most likely represents the end-phase in the consolidation of the granite magma, which was followed by pneumatolysis and the introduction of small quantities of tourmaline, cassiterite, topaz, etc.

As so small a part of the bathylith outcrops at Hartley, little can be said about it here. There appears to be a gradation from one type into another, with the more acid phases situated towards the margin.

Mr. E. C. Andrews (1916) has described marginal acid types in the Yetholme District, and assumes that such are later injections. W. J. Clunies Ross (1894) has observed similarly disposed acid rocks at Bathurst.

(e). *Occurrence of Porphyritic Types.*

Two types of porphyritic rock occur in the Hartley area, (1) a porphyritic granite round and about the village of Hartley, and (2) a granite-porphyry on Moyne Farm and on the Bathurst Road. It is of interest to note that the phenocrysts of these types are possibly of different origin.

The granite-porphyry on Moyne Farm shows a marked contrast in the size and form of phenocrysts and the crystals in the groundmass and, though no orientation has been observed, the quartz crystals are often corroded. It is concluded, therefore, that the phenocrysts of this rock are of intratelluric origin.

On the other hand, it is believed that the even-grained granite borders the porphyritic facies, and several transitional types have been collected. Moreover, a granite-porphyry, not *in situ*, has been found on the Bathurst Road, and this differs from the Moyne Farm type in containing abundant orthoclase phenocrysts. This rock possibly borders the even-grained granite (Watson, 1901; Crosby, 1900). A marginal intergrowth of plagioclase with the orthoclase phenocrysts is sometimes present, and inclusions of all the other minerals are abundant in the tabular phenocrysts. Corrosion is absent.

It is likely, therefore, that the phenocrysts of the porphyritic granite are of contemporaneous origin.

E. Age of the Intrusion.

The plutonic rocks intrude a sedimentary series of Upper Devonian age, and are overlain by Upper Marine Permian beds. This would place the age of the intrusion between Upper Devonian and Upper Marine. As many other intrusions of a somewhat similar type and of almost State-wide distribution have been shown to belong to the Kanimbla Epoch of diastrophism (Sussmilch, 1914), which closed the Devonian period, it is assumed that the Hartley plutonics are of similar age.

Summary.

1. The intrusion has been shown to be part of a composite bathylith, which forms a fairly typical calcic, plutonic complex.

2. The bathylithic rocks have been shown to comprise two series: (*a*) twelve plutonic types, and (*b*) three related hypabyssal types.

3. The petrography points to consanguinity of all these types, and the eleven chemical analyses, showing a range of more than 35% SiO_2, give corroborative testimony.

4. It has been suggested that three separate intrusions of plutonic rocks have occurred, and that these are all differentiates from a single magma.

5. It has been pointed out also that the two porphyritic types are possibly of different origin, the phenocrysts of one being intratelluric, and of the other contemporaneous.

Acknowledgments.

In conclusion, the writer wishes to thank Assistant-Professor W. R. Browne, D.Sc., for kind advice, help and encouragement during the preparation of this paper; also Miss Ida A. Brown, B.Sc., on whose Moruya paper this one has been largely modelled.

The writer also wishes to express her gratitude to many residents of Little Hartley for hospitality and help during the fieldwork.

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NOTES ON AUSTRALIAN DIPTERA. XXVII.

By J. R. MALLOCH.
(*Communicated by Dr. G. A. Waterhouse.*)

(Two Text-figures.)

[Read 25th March, 1931.]

Family CHLOROPIDAE.
Subfamily OSCINOSOMINAE.
Genus EPHYDROSCINIS Malloch.
EPHYDROSCINIS RAYMENTI Curran.

Amer. Mus. Novit., No. 422, p. 1, 10th June, 1930.

This species was described from one specimen apparently, and recorded as having been taken entering the burrows of *Halictus raymenti* Cockerell on high ground near the sea at Sandringham, Victoria, by Messrs. Rayment and Cockerell.

If the species is correctly placed as to genus, it will be readily distinguished from *australis* Malloch, the genotype and only previously described species, by the large fuscous mark on each wing, *australis* having the wings hyaline. Should it prove to belong to the genus *Parahippelates* Becker, which is distinguished from *Ephydroscinis* in the female sex merely by the presence of a variably developed curved bristle at the apex of the hind tibia on its under posterior surface, then it is very closely similar to *ornatipennis* Malloch, which has the wings marked in much the same way, but the legs in the latter are yellow at apices of femora, bases and apices of hind tibiae and all of fore and mid pair, and the three basal segments of the tarsi are also yellow, while in *raymenti* the legs are black, with the tarsi brown.

Nothing definite has been placed upon record regarding the habits of the species of the genus *Parahippelates*, but the late Dr. E. W. Ferguson stated in a letter to me some years ago that some of the species occurred on the seashore, one or more of them being remarkable for the conspicuous appearance of the specimens when they face the collector owing to the silvery face shining in the sun, and the abrupt disappearance which takes place when they turn round.

I have not seen Curran's type which is deposited in the American Museum of Natural History in New York City, N.Y.

Genus OSCINOSOMA Lioy.

This is the same generic concept as *Botanobia* Lioy of my previous papers in this series, the change being due to an interpretation of the genotypes. Later I hope to return to this matter in a revision of the Australian species; meanwhile I simply present descriptions of several species of the genus from Tasmania, which have been in my hands for some years.

OSCINOSOMA NIGROANNULATA, n. sp.

♂. Head black, frons rufous-yellow in front, with white pruinescence except on the triangle when seen from in front, face brownish, cheeks with silvery-white dust above, lower margins glossy-black, antennae, aristae, and mouth parts black. Thorax glossy-black, lateral margins of mesonotum faintly grey-dusted. Abdomen shining black. Legs yellow, coxae except apices, femora except their extreme bases and apices, and a subbasal and subapical band on each tibia, black. Wings clear. Halteres yellow, knobs whitish.

Eyes sparsely haired; frons about half the head-width, triangle broad, extending to beyond the middle of frons, postvertical and ocellar pairs of bristles of moderate size, erect and cruciate, vertical bristles and three on each orbit distinct, interfrontalia with very few hairs, two in middle of anterior margin quite distinct; parafacial not visible from the side; cheek very narrow in front, higher behind, vibrissal hair weak; antennae of moderate size, third segment orbicular; arista slender, microscopically pubescent. Mesonotum with fine short dark hairs, not punctate; scutellum with two long apical and two short subapical bristles. Legs normal, tarsi slender. Second costal division longer than first, and fully one and a half times as long as third, fourth nearly as long as third. Length, 1·75 mm.

Type: Strahan, Tasmania, 6th February, 1923 (A. Tonnoir). Type to be returned to collector.

The next three species described herein belong to a group in which the scutellum is largely or partly yellow, and the mesonotum is glossy-black except on its lateral margins. There are some other species of the group in this region but in the meantime I present a synopsis of the characters of the three now dealt with.

Synopsis of the Species.

1. Palpi, all coxae, anterior surface of fore femur on its entire extent and its posterior surface to a lesser extent, and nearly all of the third antennal segment, black; scutellum pale-yellow, only its extreme lateral basal angles black; prosternum black .... *tonnoiri*, n. sp.
   Palpi entirely, third antennal segment largely or entirely, yellow; scutellum more extensively blackened; prosternum not entirely black 2
2. All the legs and the posterior lateral angles of the frontal triangle yellow .... *tasmaniensis*, n. sp.
   Coxae, all femora, and the hind tibiae, largely blackened; frontal triangle entirely black on hind margin .... *tinctipes*, n. sp.

Of the other species described herein it may be mentioned that *nigroannulata* has the entire thorax including the scutellum glossy-black, distinguishing it from the *tonnoiri* group, and the tibiae of all legs are yellow with two black annuli, which latter character readily distinguishes it from any other Australian species so far described. The violet-black dorsum of thorax, dark halteres, and differently coloured legs will distinguish *nigroviolacea* from the other species in the present paper, and these and other characters which may be gleaned from the description will separate it from other Australian species.

The group of species included in this paper after the description of *nigroviolacea* is one in which the scutellum is largely or entirely yellow, but the mesonotum is distinctly vittate with black or fuscous instead of entirely black except the lateral margins as in the *tonnoiri* group. I present a key to the species of this group that are dealt with herein.

OSCINOSOMA TONNOIRI, n. sp.

♂. Head black, anterior two-thirds of frons, the face, lower part of second antennal segment, and lower basal angle of third, orange-coloured; triangle glossy-black; middle of cheeks yellowish; palpi black. Thorax glossy-black, upper margin of pleura and lateral margins of mesonotum orange-yellow, humeral angles suffused with fuscous on disc; scutellum lemon-yellow, black at extreme lateral basal angles. Abdomen orange-yellow, a spot on each side of first visible tergite, and the greater part of each of the other tergites black. Legs yellow, all coxae and anterior side of anterior femora black. Wings hyaline. Halteres yellow. All hairs and bristles blackish.

Eyes hairy; frons about one-half of the head-width, with numerous hairs, triangle moderately broad, rather obtuse, extending to about middle of frons; face concave, parafacials not visible from the side; third antennal segment large, a little higher than long, somewhat transverse at apex; arista pubescent; cheek narrow. Thorax smooth, with fine decumbent hairs and normal bristling; scutellum convex, with four bristles and fine black discal hairs. Abdomen stout, tapered apically. Legs long and rather stout, fore tarsi slender. Second costal division not twice as long as third; marginal cell at apex of first vein about twice as wide as submarginal at same point; fourth vein slightly arcuate on its apical section, its penultimate section more than twice as long as the penultimate section of third; inner cross-vein very distinctly proximad of apex of first vein. Length, 3 mm.

Type: Burnie, Tasmania, 25th October, 1922 (A. Tonnoir). Type to be returned to collector.

OSCINOSOMA TASMANIENSIS, n. sp.

♂, ♀. Head orange-yellow, occiput above, except its upper margin, frontal triangle except its posterior lateral angles, the aristae, and labrum, black or fuscous. Thorax glossy-black, upper margin of pleura, lateral margins of mesonotum, lower part of propleura, the prosternum, and the apex of scutellum, yellow. Abdomen yellow, a large mark on each side of first visible tergite and a fascia on hind margin of each of the other tergites which extends forward centrally, black. Legs yellow. Wings hyaline. Halteres yellow, their knobs paler. Hairs and bristles black.

Eyes hairy; frons less than one-half of the head-width, triangle large, extending about four-fifths of the distance to anterior margin, surface hairs on frons, and especially some on the posterior portions of the orbits, distinct; antennae normal in size, third segment rounded in front; arista pubescent; cheeks about half as high as width of third antennal segment. Thorax with the disc glossy, but there is a distinct aggregation of setigerous punctures on two lines in front of the dorsocentral bristles; scutellum a little pointed, the subapical pair of bristles much shorter than the apical pair. Abdomen in female more pointed than in male. Venation of wings much as in the preceding species, but the inner cross-vein is below the apex of first vein, and the third costal division and penultimate section of third vein are longer than in that species. Length, 3 mm.

Type male, and allotype, Fern Tree, Tasmania, 1st November, 1922; paratype male, Mt. Wellington, Tasmania, 7th November, 1922 (A. Tonnoir). Type to be returned to the collector.

OSCINOSOMA TINCTIPES, n. sp.

♀. Differs from *tasmaniensis* as follows: The yellow colour does not extend across the upper margin of the occiput, and the prosternum is not entirely yellow. There is less indication of a line of setigerous punctures on each side of mesonotum in line with the dorsocentrals, and the species is smaller. Length, 2 mm.

Type: Eaglehawk Neck, Tasmania, 20th November, 1922 (A. Tonnoir). Type to be returned to the collector.

This and the preceding species are quite similar to *impura* Becker, an Australian species. I have before me a large series of the latter and find that the frontal triangle is always black on its entire hind margin, the mesonotum has no well defined setigerous lines, and the legs are entirely yellow. It is thus an intermediate species between the two Tasmanian forms herein described, possessing as it does characters of both. Another Australian species, as yet undescribed, presents characters similar to *tasmaniensis* in the colour of the frontal triangle and puncturing of the mesonotum, but differs in some other characters.

OSCINOSOMA NIGROVIOLACEA, n. sp.

♀. Frons black, anterior third orange-yellow, triangle highly polished; antennae brown, third segment except its upper margin dull orange-yellow; face clear white, strongly contrasting with other parts of the head, cheeks anteriorly yellow, posteriorly fuscous, mouth parts fuscous, inner margin black; aristae fuscous. Thorax glossy-black, dorsum with a violet or purple tinge; hairs and bristles fuscous. Abdomen black, not as glossy as the mesonotum. Legs fulvous yellow, mid and hind femora, except the narrow bases and apices, black; hind tibiae black on basal halves. Wings hyaline, veins black. Knobs of halteres blackish.

Frontal triangle bare, broad, covering about three-fourths of vertex and extending about two-thirds of the distance to anterior margin; ocellar and post-vertical bristles convergent; orbits each with about seven setulae, the frons anteriorly with distinct but sparse black hairs; antennae normal; arista with short pubescence; eyes haired; cheeks narrow. Thorax with erect hairs which are most numerous in line anterior to the dorsocentrals; scutellum with a rather evident angular edge laterally, not evenly rounded off, the disc sparsely haired, margin with three pairs of setulose hairs, apical pair longest. Legs normal. Penultimate section of fourth vein as long as ultimate section of fifth and about twice as long as penultimate section of third; second costal division about one and a half times as long as third. Length, 2 mm.

Type: Sydney, February, 1925; two paratypes, 25th January, 1925. Type to be returned to Australian Museum.

QUADRISTRIATA Group.

This group is distinguished from others in the genus by the general yellow colour of the thorax, and the presence of three or four distinct black or fuscous vittae on the mesonotum. The scutellum is yellow, and the head and legs preponderantly so. I present a key to the species dealt with in this paper, but there are several more species of the group in the Australian region, some of them being now before me.

Key to the Species.

1. At most the sternopleura and hypopleura with dark markings; small species averaging about 1 mm. in length; mesonotal vittae not glossy; aristae subnude; width of

marginal cell of wing at apex of first vein not as great as width of submarginal cell at same point .... *quadristriata* Becker

Mesopleura, pteropleura, hypopleura, and sternopleura each with a blackish mark, the one on sternopleura sometimes rather faint; larger species, averaging at least 2 mm. in length; mesonotal vittae always glossy-black; arista distinctly pubescent; width of marginal cell at apex of first vein much greater than that of submarginal at same point 2

2. Third antennal segment entirely orange-yellow .... *luteicornis*, n. sp.

Third antennal segment largely dark-brown or blackish 3

3. Bristles and hairs on the scutellum and frons luteous; third antennal segment broadly infuscated .... *luteohirta*, n. sp.

Bristles and hairs on scutellum and frons black; third antennal segment narrowly infuscated above .... *nigrohirta*, n. sp.

OSCINOSOMA QUADRISTRIATA (Becker).

A very small species of a general yellowish-testaceous colour, the ocellar spot and four mesonotal vittae black, the latter sometimes partly brownish and the two in centre partly fused; third antennal segment slightly darkened at base; aristae fuscous; abdomen sometimes slightly browned dorsally; legs yellow; wings clear.

Frontal triangle slightly rounded, extending to beyond middle of frons; vertical bristles short, and, like the scattered frontal hairs, black; proboscis slender, the apical section recurved; cheek about half as high as width of third antennal segment; arista pubescent. Scutellum with four black marginal bristles, the apical pair longest, and a few blackish discal hairs. Abdomen and legs normal. Penultimate section of third vein more than half as long as penultimate section of fourth; marginal cell just beyond apex of first vein narrower than submarginal at same point. Length, 1 mm.

Localities: Como, N.S.W., swept from flowers, December, 1923 (H. Petersen). Burnie and Wilmot, Tasmania, October and January, 1922 (A. Tonnoir).

Originally described from Sydney, N.S.W.

In none of the examples before me are there any dark marks on the pleura.

OSCINOSOMA LUTEICORNIS, n. sp.

♂. Orange-yellow, with black markings as follows: Ocellar spot, a large mark in centre of occiput, four glossy vittae on mesonotum, the centre pair fused, large marks on hypopleura, pteropleura, posterior portion of mesopleura, and centre of sternopleura, the latter sometimes partly brownish, and all or almost all of metanotum. Abdomen more or less irregularly stained with fuscous on dorsum but not distinctly marked. Legs yellow. Aristae fuscous. Hairs on frons mixed black and yellow, most of those on mesonotum yellow, nearly all the femoral and tibial hairs yellow, those on the tarsi fuscous. Wings hyaline.

Eyes quite densely haired; frons dull, a little longer than wide, the triangle pointed, not sharply defined, dull, and extending to beyond middle of frons; third antennal segment orbicular, not twice as high as cheek at middle; arista pubescent. Scutellum rounded, not margined, with four black marginal bristles and numerous quite long black and some yellow hairs. Legs stronger than usual, but neither the femora nor tarsi noticeably thickened. Penultimate section of third vein not half as long as penultimate section of fourth, ultimate section of latter slightly undulated, ending almost exactly in wing-tip. Length, 2–2·5 mm.

Type: Wilmot, Tasmania, 8th January, 1922; paratypes, Adventure Bay, Tasmania, 28th December and 1st January, 1922; Cradle Valley, Tasmania, 19th January, 1922 (A. Tonnoir).

This species does not run out satisfactorily to any in Becker's key to the Indo-Australian species of *Oscinella*, none of those in section with quadristriate mesonotum being at all close in characters to it. Of the three species that fall in the segregate of the key to which this one runs, *quadristriata* has already been dealt with, *formosa* Becker has the eyes bare, mesopleura unspotted yellow, and the mesonotal vittae reddish behind and blackish only in front, while *lutea* de Meijere has the mesonotum entirely yellow and the dorsocentral bristles whitish instead of black. The wing in *lutea* has a dark apical spot. Neither of these two species is as yet known to occur in Australia, *lutea* being from New Guinea and the other from Formosa.

I have before me a specimen which agrees very well with this species but the thoracic dorsal hairs are fuscous and the abdomen is more blackened above. It is not improbable that it is a distinct species, but meanwhile I leave it aside pending the receipt of additional specimens from the mainland.

Locality.—Sydney, N.S.W., 24th September, 1924 (Health Dept.).

OSCINOSOMA LUTEOHIRTA, n. sp.

♂, ♀. Male much darker than the preceding species, general colour brownish-yellow, the legs also darker, the ventral surfaces of femora brownish and the apical segment of each tarsus of the same colour; third antennal segment almost entirely black. Female paler in colour than the male, the third antennal segment with only the apex blackened, the legs fulvous yellow. In both sexes the dorsal hairs and the vertical and marginal scutellar bristles are yellow. Structurally similar to *luteocornis*, but not as robust. Length, 2–2·5 mm.

Type male, Eaglehawk, Tasmania, 14th November, 1922; allotype, same locality, 21st November, 1922 (A. Tonnoir). Type to be returned to collector.

It is possible but hardly probable that this is a variety of *luteicornis*.

OSCINOSOMA NIGROHIRTA, n. sp.

♂. Another very similar species, differing essentially from the preceding one only in having the frontal and scutellar hairs and bristles entirely black, and the legs uniformly testaceous yellow. The central contiguous mesonotal vittae are brownish in both the specimens before me, but this is probably not a constant character in the species. The third antennal segment has a narrow blackish upper margin, and the aristae are black. Structurally similar to *luteicornis*. Length, 2·5 mm.

Type; Geeveston, Tasmania, 8th December, 1922; paratype, Sassafras, Victoria, 21st October, 1922 (A. Tonnoir). Type to be returned to the collector. Field investigation may disclose the fact that this is merely a variety of the preceding species.

A female which agrees very well with the two males described above has the anterior half of the central contiguous vittae reddish and the extreme anterior portion blackened, in this respect rather markedly resembling the species of another group in which there is a very marked red or fulvous patch on either the central pair or on both these and the sublateral vittae at the suture. In this latter group the distinction in colour is much more marked and quite abrupt while, where there is a change in colour of the vittae in the preceding group, it is gradual and not sharply defined. The female mentioned here has the dorsum of the abdomen almost entirely black.

Locality.—Sydney, N.S.W., 24th August, 1924 (Health Dept.).

It may be noted here that there are still many species in my hands which are undescribed, my present estimate of the number in the genus which are available being about 45, which may be increased or decreased upon more intensive study than I have yet been able to give to the material.

OSCINOSOMA SIMILIS (Becker).

Apparently a common and rather variable species which may be distinguished from its nearest relatives by the following characters: Frons yellow in front and black above, the large triangle glossy-black except at its extreme anterior angle, the face pure dull-white; antennae fulvous-yellow, rarely slightly darkened on upper margin of third segment; aristae fuscous; cheeks linear, yellow, with a dark line on lower margin; palpi yellow; thorax including the pleura and scutellum glossy-black, without dusting, sometimes brownish-yellow on each side behind the mesonotal suture, the hairs yellowish, the bristles black; abdomen usually black above, not as glossy as the thorax. Legs honey-yellow, with or without blackish markings as noted under the varieties below.

OSCINOSOMA SIMILIS VERA.

In this form the legs are honey-yellow, with a dark streak or broad ring on the mid and hind femora apically.

Locality.—Sydney, N.S.W., various dates from August to January except December (Health Dept. collection).

OSCINOSOMA SIMILIS APICTA, n. var.

This variety differs from the typical one in lacking the dark markings on the mid and hind femora.

Type female, allotype, and one male paratype, Sydney, N.S.W. (Health Dept.).

OSCINOSOMA SIMILIS FUSCIBASIS, n. var.

This variety differs from the typical one and *apicta* in having the bases of the hind tibiae distinctly infuscated. The mid and hind femora are distinctly infuscated as in typical *similis*. The specimens range larger than in either of the other forms, being usually at least 2 mm. in length.

Type female, and five paratype females, Sydney, N.S.W., on various dates from September to January (Health Dept.).

Genus DELTASTOMA Malloch.

DELTASTOMA ATRICORNIS, n. sp.

♀. Head testaceous-yellow, dull except on the black frontal triangle which is almost glossy; antennae yellow, third segment and aristae black; palpi yellow with the apices darkened; proboscis shining black; frontal hairs dark, the others pale. Thorax a little darker than head, with yellowish dust, the mesonotum with four dark vittae which are slightly shining but are partly obscured by the dusting; mesopleura shining reddish-brown below, pteropleura, hypopleura and sternopleura each with a black spot; scutellum yellow; all hairs and bristles dark. Abdomen dark-brown, shining, with brownish dust, genital segments yellow. Legs yellow. Wings hyaline, with a fuscous costal spot extending from apex of second to apex of third vein (Fig. 1). Halteres yellow.

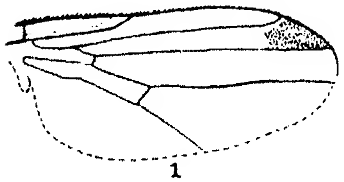
Structurally quite similar to the genotype, *unipuncta* Malloch, differing in having the frons a little wider, with a larger triangle, which extends to a little

short of middle of frons, the scutellum more convex, with six well differentiated marginal bristles, the apical pair longest, and the discal hairs much weaker, the wing a little longer, with the marginal and submarginal cells equally wide from apex of first vein to near apex of second, the latter more broadly curved to meet the costa, and no appreciable dip in the apex of third vein below the dark spot. Length, 2·5 mm.

Type: Wahroonga, Sydney, N.S.W., 24th October, 1926 (Health Dept.).

This species is readily distinguished from *unipuncta* by its coloration, the genotype having a much smaller ocellar black spot, the antennae yellow, thorax entirely yellow, as well as the palpi and proboscis.

Both types will be returned to Australia upon the completion of my work on the family.



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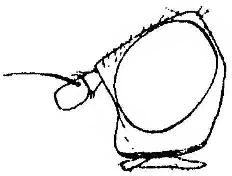

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Text-fig. 1.—Wing of *Deltastoma atricornis*, n. sp.
Text-fig. 2.—Head of *Assuania granulosa*, n. sp., from the side.

Genus SCOLIOPHTHALMUS Becker.

This genus is not included in my key to the genera of this subfamily published in a previous paper in this series, because I have no Australian examples of the only species recorded by Becker, nor in fact any representative of the genus. For reference to the Australian species see subjoined catalogue of the subfamily.

SCOLIOPHTHALMUS ALBIPILUS Becker.

This species has the thorax yellow, the mesonotum and scutellum with the exception of the humeri and a small spot behind these greyish-brown-dusted, and with sparse short white hairs, the scutellum with two pale apical bristles; pleura with distinct black spots on the mesopleura and sternopleura. The head is yellow, with the frons almost twice as wide as one eye, the triangle grey-brown-dusted, and extending only to the middle of frons. Antennae brown, third segment large, trapezoidal and with pointed front angle, the arista bare, angulate, somewhat thickened at base. Abdomen dull grey-brown on dorsum, the tergites with narrow yellow apices. Legs yellow, tarsi with brown apices, hairing white. Wings hyaline, with fine brown veins, third and fourth veins parallel. Length, 1 mm.

Locality.—Queensland. Type in the Hungarian National Museum, Budapest.

Subfamily CHLOROPINAE.

I am unable to present at this time a complete revision of the Australian species of this subfamily and confine my present contribution to descriptions of a few new species, with notes on one or two of the commoner species of the genus *Chlorops* Meigen. I take the opportunity, however, to publish a catalogue of the described species of Australia in the hope that it may prove of value to those

interested in the group. I have in my possession a number of species not dealt with herein and hope to be able subsequently to return to the matter of their description and elucidation.

Genus CHLOROMERUS Becker.

This genus was originally distinguished by its describer on the characters of the hind femora and tibiae, the former being much thickened and armed with two series of minute black spines on the apical half of the anteroventral and posteroventral surfaces and the tibiae much bent and fitting closely against the ventral surface of the femora when at rest. Unfortunately these characters are not always as clearly defined as in the genotype, and the species now dealt with was described as a *Chlorops*.

CHLOROMERUS STRIATIFRONS (Becker).

♂. Lemon-yellow, thorax and abdomen glossy. Head entirely yellow except a narrow dark-brown stripe on the frontal triangle which is black over ocelli and extends to anterior margin, the triangle glossy; aristae fuscous; occiput with a subquadrate fuscous mark in centre from vertex to neck. Thorax with five dorsal vittae which are glossy deep-black except on a portion of the middle one which is red from near anterior margin to beyond the suture in one specimen, the humeri each with a small black spot, the mesopleura, sternopleura, pteropleura, and hypopleura each with a deep-black mark; no black mark below prothoracic spiracle; postnotum glossy-black; scutellum yellow. Abdomen with a fuscous fascia on each of the four visible tergites, which is along anterior margin. Legs yellow, with rather faint dark marks on middle of anterior and posterior femora and middle of posterior tibiae. Wings hyaline. Halteres yellow.

Frontal triangle smooth and polished, extending across vertex and to anterior margin; ocellar setulae small, proclinate and divergent; face slightly retreating to mouth margin, and concave in profile; cheek a little narrower than third antennal segment. Mesonotum with but one pair of prescutellar and one postalar bristle; scutellum almost convex on disc, with two rather prominent apical and two much shorter subapical black bristles. Hind femur much as in *gracilis* Malloch, hardly twice as thick as the mid femur, the two series of short black bristles visible only with a very high power lens; hind tibiae bent at bases only, not as strikingly so as in the genotype and the earlier described species. Second costal division very little longer than first or third, the latter two practically equal in length. Length, 2 mm.

Localities.—St. Patrick R., Geeveston and Fern Tree, Tasmania; Forbes, N.S.W.

This species rather weakens the claim to separation of the genus from *Chlorops*, as the hind femur is much more slender than in the genotype of *Chloromerus*, but it is still possible to relegate it to that genus on the basis of the biserial armature of the femora, though in certain species of *Chlorops* now before me there is a tendency to a production of even this feature, the hind femora having a single weak series of spines.

Genus ASSUANIA Becker.

This genus is not a remarkably well defined one, the only characteristic feature being the angulate upper apical extremity of the third antennal segment, shown in Figure 2. Becker to a considerable extent made use of colour characters

in his generic segregations, but in dealing with the Australian species he pointed out that the two European species of the genus have the scutellum yellow, the single African species known to him has the scutellum partly dark, and the Australian species have it entirely black. The new species before me agrees in this respect with its Australian congeners. I have not seen the genotype.

For the guidance of Australian students I present below a diagnosis of the native species based upon Becker's descriptions and the species now described.

Key to the Species.

1. Palpi entirely yellow; third antennal segment yellow, infuscated above; cheek almost twice as high as width of third antennal segment; legs rusty-yellow, with brownish tarsi and a brown cloud on femora and tibiae; aristae very slender .... *nigroscutellata* Becker

   Palpi black or fuscous; third antennal segment black or largely so; cheek not noticeably higher than width of third antennal segment; legs more extensively blackened 2

2. Third antennal segment entirely black; legs black, apices of femora and tibiae and bases of latter yellow; aristae exceptionally thick for this genus; pleura entirely dark .... *grossiseta* Becker

   Third antennal segment yellowish below on at least the inner side; legs largely yellow, the femora, hind tibiae except their apices, fore tarsi, and the apical two segments of mid and hind tarsi, black; aristae thickened at bases, tapering off on basal fourth; pleura glossy-black, the upper margin of sternopleura yellow .... *granulosa*, n. sp.

ASSUANIA GRANULOSA, n. sp.

♂, ♀. Frons brown, anterior margin conspicuously yellow, triangle glossy-black, occiput shining black, face and cheeks yellowish-testaceous, dull, with whitish dust, centre of face slightly darkened below, cheek with a black line on lower margin; antennae black, third segment with the lower half yellowish on inner side and less noticeably yellowish on outer side; aristae fuscous on the thickened basal fourth, paler beyond; palpi fuscous. Thorax black, glossy on pleura and the mesonotal vittae, the latter five in number but the sublateral and submedian vittae fused so that there appear to be but three broad shining vittae on a grey-dusted ground, the central vitta broad in front, becoming linear about midway between the suture and hind margin and continuing thus to the margin; upper margin of sternopleura yellow; scutellum shining-black. Abdomen shining-black, apex of apical tergite narrowly yellowish. Legs yellow, entire femora and fore tarsi, hind tibiae except their apices, and the two apical segments of mid and hind tarsi black. Wings slightly clouded, the veins thick and fuscous. Halteres with the knobs white.

Frons at vertex one-half of the head width, with some fine black surface hairs, the triangle falling short of eyes at vertex by about one-fourth of its width at that point, and extending to anterior margin, the sides straight and the surface polished; all four vertical setulae small, the ocellars very fine and short, directed forward and divergent; profile as Figure 2; cheek hardly higher than width of third antennal segment; aristae pubescent. Thorax with the dorsum granulose, especially on the more shining vittae, the pleura smooth and polished, all bristles very short and fine, the anterior notopleural indistinguishable in all three specimens, the posterior pair distinct; scutellum flattened on disc, apical bristles very short. Second costal division but little longer than first and about one and one-fourth as long as third, penultimate section of fourth vein nearly as long as ultimate section of fifth. Length, 2·5-3·5 mm.

Type, female, and allotype, Cradle Valley, Tasmania, 23rd January, 1923; one female paratype, same locality, 12th January, 1923 (A. Tonnoir).

The wings of the two previously described species are entirely hyaline.

Genus Chlorops Meigen.

Chlorops grossa, n. sp.

♀. *Head* testaceous-yellow, frontal triangle black, shining, with slight brownish-dust centrally, occiput with a large subquadrate brownish mark in centre from vertex to neck, antennae yellow, third segment and aristae broken off in both specimens, palpi yellow, with black apices. Thorax coloured as head, with five black vittae which are but slightly shining because of the presence of grey dust on their entire extent, the median and submedian vittae tapered off behind, the sublaterals present behind suture only, and rudimentary; pleura with five black marks, one below the prothoracic spiracle, the others on the mesopleura, sternopleura, pteropleura, and hypopleura; scutellum broadly browned on disc; postnotum fuscous. Abdomen yellow, with the exposed dorsal area of each tergite except the narrow posterior margin dark brown or fuscous. Legs yellow, femora variably stained with brown or fuscous, tibiae less noticeably darkened, but the hind pair usually with a fuscous annulus beyond middle, several of the apical segments of fore tarsi and the fifth in mid and hind pairs fuscous. Wings slightly smoky, all veins brown. Halteres yellowish-white.

Frons at vertex nearly one-half of the head-width, slightly longer at centre than its width at vertex, triangle narrow, about three-fifths of the vertical width at posterior extremity and continued to anterior margin, with a deep central sulcus and about three more slender deep sulci on each side parallel to the lateral margins, vertical bristles represented by minute fine hairs, the ocellars indistinguishable, the surface hairs as long as the vertical bristles; eyes a little longer than high, almost bare; face retreating below, the frons projecting farther beyond eyes than height of cheek, the latter about one-third as high as eye and higher than width of parafacial; antennae broken; palpi normal. Thorax with scattered black hairs and the usual bristles; scutellum with discal hairs and four apical bristles. Abdomen elongate, with fine black hairs. Legs normal, fore tarsi not widened. Wings elongate, the ultimate section of fourth vein more distinct than usual; its penultimate section a little longer than penultimate section of third and about three-fourths as long as ultimate section of fifth. Length, 6·5 mm.

Type: King River, Tasmania, 4th February, 1923; one paratype, Wilmot, Tasmania, 8th January, 1923 (A. Tonnoir).

Chlorops scutellaris Becker.

The species has the frontal triangle almost entirely smooth, without either central or lateral sulci, and mostly black, the palpi black, and third antennal segment largely infuscated, the aristae fuscous. Thorax with five shining black vittae, and all pleural sclerites distinctly black-spotted, the scutellum black on each side and more or less broadly yellow in centre. Legs yellow, femora almost entirely black, the hind and sometimes also the mid tibiae infuscated centrally.

A rather slender species, with the hind femora hardly thicker than the mid pair and though there is a series of microscopic wart-like elevations on the apical third or more of the posteroventral surface there are practically no such elevations on the anteroventral surface. It is possible that this species may yet

be removed to the genus *Chloromerus* along with *striatifrons* Becker, a course adopted for the latter herein, but in the meantime I leave it in the genus in which it was described. There are several other species of a similar doubtful status now before me. Length, 2·5–3 mm.

Originally described from New South Wales, and represented in the material before me from Como, N.S.W., December, 1928 (H. Petersen); National Park, 15th December, 1922, Burnie, 31st January, 1923, and Geeveston, 7th December, 1922, all in Tasmania (A. Tonnoir).

CHLOROPS CANALICULATA Becker.

I accept as this species a specimen which agrees so closely with Becker's description that I consider there can be no reasonable doubt as to the correctness of the identification though the type series of the species came from Formosa.

The species belongs to that group in which the frontal triangle is finely longitudinally furrowed or striate on its entire extent, there being in this case two or three such deep complete furrows on each side and no central anterior shallower sulcus. An additional distinguishing character is found in the colour of the aristae which are yellowish-white, an uncommon character in the genus which is duplicated in at least two other species now before me. The palpi are yellow, the frons yellow with a slightly shining black triangle, the third antennal segment is yellow with the upper margin rather broadly infuscated. The thoracic vittae are broad, black, and dull because of a covering of grey dust, the scutellum is fuscous with the margin yellow, and though there are the usual dark spots on the pleura they are not uniformly black, the one on the sternopleura being usually reddish-yellow. The legs are yellow, with apices of tarsi infuscated. Length, 2·5–3 mm.

Original locality, Formosa, and represented by one specimen now before me from Como, N.S.W., December, 1928 (H. Petersen).

CHLOROPS STIGMATELLA Becker.

This species has the aristae similarly coloured to those of the preceding one, and the antennae, palpi, thoracic vittae, and legs are almost identical in colour also. But the frontal triangle is brownish-black, glossy, with the posterior margin and a spot on each side in front of the ocellar elevation yellow, the surface smooth except for a shallow central sulcus anterior to the ocelli which extends to the linear anterior projection, the latter reaching anterior margin of frons, and in addition to the sulcus there is a single well-defined marginal impressed line on the entire length of the wide part of the triangle on each side. The scutellum is entirely yellow and the pleura are yellow, with but a faintly indicated reddish mark on the lower margin of mesopleura and a larger one on lower portion of the sternopleura, and a small deep black spot below the prothoracic spiracle. Length, 3 mm.

Originally described from New South Wales and Formosa. I have a number of specimens before me from Mosman, and Sydney, N.S.W., two of them taken on windows, in the months of October and April (Health Dept.).

CHLOROPS PALLIDISETA, n. sp.

♀. A darker species than the preceding one, the general ground colour being brownish-yellow, and distinctly less shining. Head brownish-yellow, the frontal

triangle glossy-black; third antennal segment broadly infuscated above and at apex; occiput with a large black central quadrate mark; palpi yellow; aristae yellow on the swollen basal portion, white beyond. Thoracic dorsum brownish-dusted, with the five black vittae shining, but not highly glossy because of the overlying brown dust, the intervening stripes rather dark brownish-yellow; pleura almost entirely glossy-black, but the type pinned through the side so that the details are not distinguishable; scutellum yellow in centre, black on sides; hairs and bristles dark. Abdomen fuscous, shining but not distinctly marked in the type which is slightly teneral. Legs testaceous yellow, all femora, and the mid and hind tibiae browned in middle, the tarsi brown apically. Wings slightly brownish, veins dark brown. Halteres yellow.

Frons longer than wide, the triangle distinctly separated from the eyes at the vertex, and extending to anterior margin, its surface highly polished, the sides almost straight so that there is no linear anterior production; the four vertical bristles rather well developed for this genus, the ocellars very short and fine; third antennal segment a little longer than its greatest width, the upper apical extremity not evenly rounded; arista thick at base, with rather dense white pubescence; palpi normal. Thorax without abnormal features, the scutellum with two rather long apical and two much shorter preapical bristles. Legs slender, fore tarsi not thickened, hind femora not distinctly thicker than mid pair and without ventral armature. Third and fourth wing-veins divergent at apices, penultimate section of fourth more than twice as long as penultimate section of third and about three-fourths as long as ultimate section of fifth. Length, 3 mm.

Type: Sydney, N.S.W., 9th October, 1921 (Health Dept.). One specimen.

C. ochrostoma Becker has also a pale arista, but it is not known to occur outside New Guinea and is distinguished from the others in this paper which have a similarly coloured arista by the entirely yellow frontal triangle and other characters.

CHLOROPS NUBILIPALPIS, n. sp.

♂, ♀. Very similar to *scutellaris* Becker in general colour and habitus, differing in having the frontal triangle glossy brownish-black, darker in the central anterior sulcus, the thoracic ground colour paler yellow, and the scutellum pale-yellow with only a small black mark on each basal angle. The femora are glossy-black, all tibiae are slightly darkened centrally, the hind pair more distinctly so than the others, and the tarsi are brown apically.

Structurally the species is readily distinguished from *scutellaris* by the presence of a rather broad shallow sulcus which extends from in front of the ocelli to its anterior extremity, causing the triangle to be more nearly straight on its sides than is that of *scutellaris*, in which species there is a rather evident emargination of the sides anteriorly so that the apex is linear. I cannot detect any posteroventral armature of the hind femora in the new species even with the highest power lens available to me, while this armature is quite evident with a lower power in *scutellaris*. The hind femora in *nubilipalpis* are also not as thick as in *scutellaris*. In other respects the two species are almost identical, the dark spots on the pleura being the same in size and arrangement in both even to the humeral and infraspiracular dots. Length, 3 mm.

Type: Lake Margaret, Tasmania, 3rd February, 1923 (A. Tonnoir); one paratype, same date and collector.

CHLOROPS ALBIFRONS Walker.

I have before me several specimens which I refer to this species with a slight doubt. It is one of the intermediate group between this genus and *Chloromerus* Becker, having the hind femora slightly thicker than the mid pair and with one series of microscopic setules and a rudimentary one opposite it for a part of the extent of the apical third. The hind tibia is very slightly curved at the base, and in other respects the species is quite similar to *striatifrons* Becker described in this paper. It differs from that species, and in fact every other one from Australia in both the genera, in having the frontal triangle entirely glossy-yellow and without sulci or striae. Walker states that the antennae and palpi are fulvous, but in the only specimen of those before me in which the antennae are intact the third segment is partly infuscated. The general coloration is very similar to that of *striatifrons*, the thorax having five glossy-black vittae, and the scutellum being yellow. The pleura have usually three black spots in addition to the small one below the prothoracic spiracle, but there may be one or more of them partly rufous or orange. The legs are yellow, with the apical two or three segments of each tarsus generally darkened. Length, 3 mm.

Originally described from Adelaide, and unknown to Becker who retained it in *Chlorops*. The specimens before me are from Como, N.S.W., December, 1928 (H. Petersen).

Because of the rather damaged condition of all five specimens available, I am deferring a definite opinion on the generic status of the species, but it is undoubtedly distinct from any other in both genera now known to me or included in Becker's paper. Of the species definitely recorded from Australia by Becker, there remain but three unknown to me, *sulcata* Becker, *carinata* Becker and *pictipes* Becker, but I have several as yet undescribed species in hand which I hope to be able to include in a future paper on the family along with complete keys to this genus and also to *Oscinosoma* Lioy, to neither of which genera I have yet published keys. Pending the publication of my keys students may consult the paper by Becker on the Indo-Australian Chloropidae in which most of the species of the subjoined catalogue were described.

Catalogue of the Described Australian Chloropidae.

In this catalogue I include all species which are definitely referred to this family up to and including the present paper, so that students of these insects may have a ready reference to the location of the descriptions. I give only the first reference to, or Australian record of, species in all cases, and cite the genotypes, most of which are not Australian.

It may be of interest to note that Tillyard in his "Insects of Australia and New Zealand" estimates the number of species of the family from Australia as 50, a very conservative estimate indeed. There probably are several hundred species in Australia, the present contribution bringing the total to 97.

Family CHLOROPIDAE.

Subfamily OSCINOSOMINAE.

I. Genus PARAHIPPELATES Becker* (1911, p. 109). Genotype, *Oscinis pulchrifrons* de Meijere.

* References to papers in this catalogue are Becker, 1911, *Ann. Mus. Nat. Hungary*, vol. ix; Malloch, 1923-1928, PROC. LINN. SOC. N.S.W., vols. xlviii (1923)-liii (1928); Skuse, 1889, PROC. LINN. SOC. N.S.W., (2), iv, 1889; Thomson, 1869, *Eugen. Resa*, Dipt.

1. *nudiseta* Becker, 1911, p. 113. Sydney, N.S.W.—2. *ornatipennis* Malloch, 1923, p. 620. Victoria.—3. *brunneicosta* Malloch, 1923, p. 620. Queensland.—4. *duplicata* Malloch, 1923, p. 621. Melville Island.—5. *costomaculata* Malloch, 1924, p. 329. N.S.W.—6. *albiseta* Malloch, 1924, p. 330. Queensland.—7. *fuscipes* Malloch, 1924, p. 330. N.S.W.—8. *aequalis* Becker, 1911, p. 111. New Guinea; Malloch, 1924, p. 331. N.S.W.—9. *anomala* Malloch, 1925, p. 96. N.S.W., S.A.—10. *seticauda* Malloch, 1928, p. 302. N.S.W., Vict.—11. *parva* Malloch, 1928, p. 302.—12. *dasypleura* Malloch (subgenus *Terraereginia*), 1928, p. 303. Queensland.

II. Genus EPHYDROSCINIS Malloch, 1924, p. 331. Genotype, *E. australis* Malloch.

13. *australis* Malloch, 1924, p. 331. N.S.W.—14. *raymenti* Curran, *Amer. Mus. Novit.*, No. 422, 1930, p. 1. Vict.

III. Genus EUHIPPELATES Malloch, 1925, p. 96. Genotype, *E. pallidiseta* Malloch.

15. *pallidiseta* Malloch, 1925, p. 96. N.S.W.—var. *pallipes* Malloch, 1925, p. 97. N.S.W.

IV. Genus CADREMA Walker, *Proc. Linn. Soc. London*, iv, 1860, p. 117. Genotype, *C. lonchopteroides* Walker.

16. *atriseta* Malloch, 1924, p. 355 (*Gaurax*). N.S.W.—17. *bancrofti* Malloch, 1925, p. 97 (*Hippelates*). Queensland.—18. *fergusoni* Malloch, 1927, p. 438 (*Hippelates*). N.S.W.—19. *atricornis* Malloch, 1927, p. 438 (*Hippelates*). N. Queensland.—20. *nigridorsata* Malloch, 1927, p. 439 (*Hippelates*). Tasmania.—21. *unimaculata* Malloch, 1927, p. 439 (*Hippelates*). Tasmania.—22. *abbreviata* Malloch, 1927, p. 440 (*Hippelates*). Tasmania.

V. Genus BATRACHOMYIA Skuse, 1889, p. 175. Genotype, *B. nigritarsis* Skuse.

23. *nigritarsis* Skuse, 1889, p. 175. N.S.W.—24. *quadrilineata* Skuse, 1889, p. 176. N.S.W.—25. *atricornis* Malloch, 1925, p. 336. N.S.W.—26. *flavicornis* Malloch, 1925, p. 336. N.S.W.—27. *major* Malloch, 1927, p. 440. Tasmania.—28. *strigipes* Malloch, 1927, p. 441. Tasmania.

VI. Genus THYRIDULA Becker, 1911, p. 94. Genotype, *T. breviventris* Becker.

29. *atroapicata* Malloch, 1924, p. 358. N.S.W.—30. *centralis* Malloch, 1925, p. 396. N.S.W.—31. *rugosa* Malloch, 1926, p. 546; 1927, p. 441 (subgenus *Euthyridula*, as subgenotype). N. Queensland.—32. *brunneifrons* Malloch, 1927, p. 442. Tasmania.

VII. Genus TRICIMBA Lioy, *Atti Inst. Venet.*, ser. 3, vol. 9, 1864, p. 1125. Genotype, *Oscinis cincta* Meigen.

33. *carinata* Malloch, 1924, p. 356. N.S.W.—34. *scutellata* Malloch, 1925, p. 337. N.S.W.—35. *carinifacies* Malloch, 1927, p. 443. Tasmania.—36. *pollinosa* Malloch, 1927, p. 443. N.S.W., W.A.—37. *convexa* Malloch, 1927, p. 444. Tasmania.—38. *similata* Malloch, 1927, p. 444. N.S.W.

VIII. Genus SIPHUNCULINA Rondani, *Dipt. Ital. Prod.*, vol. 1, 1856, p. 128. Genotype, *S. brevinervis* Rondani.

39. *breviseta* Malloch, 1924, p. 358. N.S.W.

IX. Genus PLATYINA Malloch, 1927, p. 436. Genotype, *P. nebulifera* Malloch.

40. *nebulifera* Malloch, 1927, p. 436. Tasmania.

X. Genus BENJAMINELLA Malloch, 1925, p. 336. Genotype, *B. albifacies* Malloch.

41. *albifacies* Malloch, 1925, p. 337. Tasmania, N.S.W.

XI. Genus DELTASTOMA Malloch, 1924, p. 359. Genotype, *D. unipuncta* Malloch.

42. *unipuncta* Malloch, 1924, p. 359. N.S.W.—43. *atricornis* Malloch, present paper.

XII. Genus CAVICEPS Malloch, 1924, p. 355. Genotype, *C. flavipes* Malloch.

44. *flavipes* Malloch, 1924, p. 356. N.S.W.

XIII. Genus SCOLIOPHTHALMUS Becker, *Mitt. Zool. Mus. Berlin*, vol. 2, pt. 3, 1903, p. 147. Genotype, *S. trapezoides* Becker. Egypt.

45. *albipilus* Becker, 1911, p. 115. Queensland.—46. *vicarius* Walker, *List Ins. Brit. Mus.*, Diptera, pt. 4, 1849, p. 1120 (*Chlorops*). Australia.

XIV. Genus OSCINOSOMA Lioy, *Atti Inst. Veneto*, ser. 3, vol. 9, 1864, p. 1125. Genotype, *Chlorops vitripennis* Meigen.

47. *mesopleuralis* Becker, 1911, p. 150 (*Oscinella*). Queensland.—48. *impura* Becker, 1911, p. 150 (*Oscinella*). N.S.W.—49. *subpilosa* Becker, 1911, p. 150 (*Oscinella*). N.S.W.—50. *similifrons* Becker, 1911, p. 152 (*Oscinella*). N.S.W.—51. *similis* Becker, 1911, p. 153 (*Oscinella*). N.S.W.; var. *apicta* Malloch, present paper. N.S.W.; var. *fuscibasis* Malloch, present paper. N.S.W.—52. *quadristriata* Becker, 1911, p. 154 (*Oscinella*). N.S.W.—53. *tibiella* Becker, 1911, p. 155 (*Oscinella*). N.S.W.—54. *pruinosa* Thomson, 1869, 605, 307 (*Oscinis*). N.S.W.—55. *punctulata* Becker, 1911, p. 158 (*Oscinella*). N.S.W.—56. *selachopina* Thomson, 1869, 606, 306 (*Oscinis*). N.S.W. [*Tricimba*?].—57. *nigroannulata* Malloch, 1925, p. 338 (*Botanobia*). N.S.W.—58. *dilata* Malloch, 1925, p. 339 (*Botanobia*). N.S.W.—59. *tonnoiri* Malloch, present paper. Tasmania.—60. *tasmaniensis* Malloch, present paper. Tasmania.—61. *nigroannulata* Malloch, present paper. Tasmania.—62. *nigroviolacea* Malloch, present paper. N.S.W.—63. *tinctipes* Malloch, present paper. Tasmania.—64. *luteicornis* Malloch, present paper. Tasmania.—65. *luteohirta* Malloch, present paper. Tasmania.—66. *nigrohirta* Malloch, present paper. N.S.W.

XV. Genus GAURAX Loew, *Berl. Ent. Zeitschr.*, vol. 7, 1863, p. 35. Genotype, *G. festivus* Loew.

67. *apicipunctata* Malloch, 1927, p. 444. N.S.W.

Subfamily CHLOROPINAE.

XVI. Genus PACHYLOPHUS Loew, *Ofvers. K. Vet. Akad. Forh.*, 1856, p. 225. Genotype, *P. lugens* Loew.

68. *lutea* Malloch, 1925, p. 95. Queensland.—69. *secundus* Malloch, 1927, p. 429. W.A.—70. *alienus* Malloch, 1927, p. 429. N.S.W.

XVII. Genus CHLOROMERUS Becker, 1911, p. 40. Genotype, *C. purus* Becker.

71. *purus* Becker, 1911, p. 40. N.S.W.; var. *varians* Malloch, 1927, p. 433. N.S.W.; var. *maculifera* Malloch, 1927, p. 433. Tasmania.—72. *pallidior* Becker, 1911, Queensland.—73. *nigrifemur* Malloch, 1927, p. 431. Tasmania.—74. *maculifemur* Malloch, 1927, p. 432. Tasmania.—75. *gracilis* Malloch, 1927, p. 432. N.S.W.—76. *trimaculata* Malloch, 1927, p. 433. N.S.W.—77. *striatifrons* Becker, 1911, p. 57 (*Chlorops*). N.S.W.

XVIII. Genus CHLOROPELLA Malloch, 1925, p. 94. Genotype, *C. bipartita* Malloch.

78. *bipartita* Malloch, 1925, p. 94. N.S.W.

XIX. Genus CHLOROPS Meigen, *Illiger's Mag.*, vol. 2, 1803, p. 278, no species; *Syst. Beschr.*, vol. 6, 1830, p. 140. Genotype, *C. laeta* Meigen.

79. *scutellaris* Becker, 1911, p. 58. N.S.W.—80. *sulcata* Becker, 1911, p. 58. N.S.W.—81. *stigmatella* Becker, 1911, p. 59. N.S.W.; Formosa.—82. *carinata* Becker, 1911, p. 59. N.S.W.—83. *pictipes* Becker, 1911, p. 60. N.S.W.—84. *albifrons* Walker, *List. Ins. Brit. Mus.*, Diptera, pt. 4, 1849, p. 1121. Adelaide. 85. *canaliculata* Becker, 1911, p. 71. Formosa.—86. *grossa* Malloch, present paper. Tasmania.—

87. *pallidiseta* Malloch, present paper. N.S.W.—88. *nubilipalpis* Malloch, present paper. Tasmania.

XX. Genus DIPLOTOXA Loew, *Berl. Ent. Zeitschr.*, vol. 7, 1863, p. 54. Genotype, *Chlorops versicolor* Loew.

89. *tasmaniensis* Malloch, 1927, p. 434. Tasmania.

XXI. Genus CHLOROPSINA Becker, 1911, p. 51. Genotype, *C. oculata* Becker.

90. *nigrohalterata* Malloch, 1924.

XXII. Genus ASSUANIA Becker, *Mitt. Zool. Mus. Berlin*, vol. 2, pt. 3, 1903, p. 149. Genotype, *A. glabra* Becker.

91. *nigroscutellata* Becker, 1911, p. 81. N.S.W.—92. *grossiseta* Becker, 1911, p. 82. N.S.W.—93. *granulosa* Malloch, present paper.

XXIII. Genus CHLOROPISCA Loew, *Zeitschr. Ent. Breslau*, vol. 15, 1866, p. 79. Genotype, *Chlorops glabra* Meigen.

94. *subnotata* Malloch, 1927, p. 429. N.S.W.—95. *monticola* Malloch, 1927, p. 430. N.S.W.

XXIV. Genus FORMOSINA Becker, 1911, p. 78. Genotype, *Chloropisca lucens* de Meijere.

96. *australis* Becker, 1911, p. 80. Queensland.

XXV. Genus PEMPHIGONOTUS Lamb, *Ann. Mag. Nat. Hist.*, ser. 8, vol. 19, 1917, p. 54. Genotype, *P. mirabilis* Lamb.

97. *mirabilis* Lamb, *l.c.*, p. 35. Melville Is.

Family MILICHIIDAE.

The present group has generally been accepted as a subfamily of Agromyzidae, and was so considered by me in a previous paper in this series, but the most recent work on the acalyptrate Diptera by Hendel gives the rank of family and I am tentatively accepting this conclusion. I present some data upon one genus.

Genus MILICHIELLA Giglio-Tos.

Becker (*Ann. Mus. Nat. Hungar.*, vol. 5, 1907, p. 507) published a revision of the subfamily Milichiinae and in it he gave synopses of all the species of this and other genera then known to him. In *Milichiella* he included a number of species which he had not seen, the total being 17. No species was recorded from Australia and only two from as close as New Guinea. Of the latter one, *lacteipennis* Loew, has been recorded in this series of papers, the other, *argentea* Fabricius, is not known to me. There are apparently three species of the genus now in my hands, though one of them is represented by a single specimen which lacks the head and I may be in error in placing it in this genus. Its other characters are so closely in agreement with those of the other species that I believe I am correct in my conclusions regarding its generic position. The three may be distinguished as in the key below, but only in the male sex, as the females are unknown to me, except *lacteipennis*. It is extremely probable that the females of all three species lack silvery dust on the dorsum of the abdomen which is characteristic of other species already known from other faunal regions.

Key to the Species (Males).

1. Abdomen entirely black, glossy except for a portion of tergites 3 and 4 (second and third visible); second and fifth tergites each longer than third and fourth combined, fifth tapered apically, the sides rounded over and with long hairs below curve which extend upwards as a loose fringe; legs black; knobs of halteres yellow; squamae whitish .... *lacteipennis* (Loew)

Abdomen densely silvery-white-dusted on dorsum; second tergite longer than fifth, the latter slightly narrowed at apex, not longer than third and fourth tergites combined; knobs of halteres black or fuscous 2

2. Legs, including the tarsi, black; all abdominal tergites with brightly shining silvery dust and two series of black setulose hairs centrally at apex, which become more numerous, generally triseriate laterally, the fifth tergite with some scattered hairs on disc, but none centrally in front .... *nigripes*, n. sp.

Tarsi yellowish, remainder of legs black; dust on dorsum of abdomen not brightly shining, rather dull, the third and fourth tergites with scattered hairs in about three series which cover almost all of the area, fifth with some hairs on about the central half, which extend to anterior margin of the exposed portion .... *lacteivcntris*, n. sp.

Milichiella lacteipennis (Loew).

It may be difficult to distinguish the females of the next two species from this, but in *nigripes* the halteres and margins of the squama are black, and the frontal triangle is more deeply sunken and narrower, while the pale tarsi and dark halteres should serve to separate *lacteiventris*.

Milichiella nigripes, n. sp.

♂. Head and thorax deep-black, interfrontalia slightly shagreened, giving it a rather dull appearance as compared with the glossy triangle, mesonotum without a trace of dusting of any kind. Abdomen densely covered with bright silvery dust except on the rudimentary first tergite, each anterior lateral angle of second, and the apex of fifth. Legs black. Wings hyaline. Squamae and knobs of halteres black.

Frons at vertex about one-third of the head-width, narrowed to anterior margin, each orbit with the upper bristle recurved, the second proclinate, and two or three anterior incurved bristles; interfrontalia slightly shagreened and with a series of minute incurved hairs on each side of central line which converge anteriorly; face as wide as anterior margin of frons, glossy on upper, dull on lower half, the series of bristles on each side rather fine, the uppermost one longest; cheeks practically obliterated. Thoracic dorsum with numerous rather long black hairs, two pairs of postsutural dorsocentrals, and two bristles on each anterior lateral area; sternopleural with two long and several shorter bristles; scutellum with slight evidence of brownish dust, the disc bare, bristles four. Second abdominal tergite longest, longer than fifth, but not longer than third and fourth combined, fifth slightly longer than fourth, the apical margin of each with at least one, usually two, series of hairs centrally and generally at least three series laterally, fifth with the anterior central portion bare. Legs normal, mid femur with the usual rather dense setulose hairs on anteroventral surface apically. First posterior cell distinctly narrowed apically, almost as in *lacteipennis*. Length, 2–2·5 mm.

Type and two male paratypes, one lacking the head, February, 1924 (Health Dept.).

This species is very similar to one occurring in the Philippines, but differs from the latter in having entirely black legs, glossy mesonotum, and more numerous hairs on the apices of the abdominal tergites.

Milichiella lacteiventris, n. sp.

♂. Very similar to the preceding species, differing in the duller white of the abdomen, in the pale tarsi, and the slightly brownish dusted mesonotum. The squamae are also paler. In addition to the character of the hairing of the

abdominal tergites it should be noted that the second tergite is distinctly longer than the fifth, and than the third and fourth combined, and the fifth is about as long as the two preceding combined. Length, 2 mm.

Type: Eidsvold, Queensland. No other data.

Family Tachinidae.

Tribe Rutiliini.

Genus Rutilia Robineau-Desvoidy.

In the paper previously referred to herein under the family Chloropidae, Curran has described three species belonging to this genus, all of which he places close to *formosa* Robineau-Desvoidy. I offer some notes on the species.

Rutilia pallens Curran.

This species possesses an anterior sternopleural, and pubescent aristae. It is undoubtedly referable to the subgenus *Senostoma* Macquart, and is probably the same as *hirticeps* Malloch, though it is impossible to be certain of this without an examination of the type which I have not seen. This is deposited in the American Museum of Natural History, in New York City.

Locality, New South Wales, no other data.

Rutilia formosina Curran.

This species evidently belongs to the *formosa* group, but it is impossible to tell from the description if it has been listed by me in any of my papers on the genus, as there is no mention by Curran of the nature of the hind tibial armature and certain other essential characters. I assume that the length given as 4 mm. is an error, possibly for 14 mm.

Locality, Australia, no other data.

Rutilia corona Curran.

Distinguished from the preceding species in Curran's synopsis by the pile of the parafacials being rather "long and coarse and usually mostly black", instead of "short and fine and yellowish in colour".

Locality, New South Wales, three males, no other data. Type in same collection as the other two.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE ACTINOMYCETALES. I.

A CASE OF HEREDITARY VARIATION IN THE GENUS ACTINOMYCES.

By H. L. JENSEN, Macleay Bacteriologist to the Society.

(Plate iii; eleven Text-figures.)

[Read 29th April, 1931.]

In a microbiological analysis of a soil from a lawn in the grounds of Sydney University in search of organisms of the genus *Micromonospora* (Ørskov, 1923; Jensen, 1930) the writer isolated an organism which seemed difficult to locate, since it exhibited characters belonging to both of the genera *Actinomyces* and *Mycobacterium*, which are not very well separated from each other. In quite young cultures it formed branching filaments, which soon broke up into short, rod-shaped, partly acid-fast elements; in this stage the organism could not be distinguished from the ordinary saprophytic mycobacteria (*Myc. phlei, lacticola*, etc.). In some instances, 4–5 weeks old cultures produced spots of white aerial mycelium, like that which is characteristic of most actinomycetes; by plating from this mycelium, cultures were obtained of an organism, which consisted of a richly branching mycelium, entirely actinomyces-like, and without any tendency to spontaneous "fragmentation". Another organism behaving similarly was later isolated from another soil from a flower bed. It might be imagined that the cultures had, from the beginning, represented mixtures of two different organisms, but in view of the occurrence of the phenomenon in two different strains it seemed more likely to be what has been variously described as "bacterial mutation", "clone transformation", "saltation", "microbial dissociation", or "cyclogeny". Since this has an important bearing on the classification of microorganisms it was decided to subject the phenomenon to a closer study, in connection with a more general investigation of the occurrence and activities of actinomycetes in Australian soils.

Review of the Literature.

The phenomenon referred to above is intimately bound up with the whole problem of microbial variation and life cycles in bacteria. Since the literature on this subject is too vast to be reviewed here (for references, see Löhnis, 1921, Hadley, 1927, and Arkwright, 1930), we will deal only with the contributions referring to hereditary changes in the genera *Corynebacterium*, *Mycobacterium*, and *Actinomyces*. Metchnikoff (1888), Bruns (1895) and Coppen-Jones (1895) noted the occurrence of long, sometimes richly branching filaments in old cultures of the tubercle bacillus, which led them to regard this organism as a developmental stage of a more highly differentiated fungus. A permanent transformation to such a form was, however, not observed, and would indeed have met with little

confidence in that era of monomorphistic views. Kitt (1897) found an actinomyces-like organism arising in broth-cultures of *Bact. erysipelatos suum*, of which he believed it to be a developmental form; later, however, he revoked his first statement, attributing it to an error caused by a "tenacious symbiosis" between the bacterium and a contaminating actinomyces; it seems difficult today to see which of these alternatives is correct. Two interesting contributions were furnished by Cache (1901) and Spirig (1903). They found in old cultures of *Corynebact. diphtheriae* a filamentous organism, which could be isolated, and appeared like an actinomyces. Spirig observed a formation of aerial mycelium in this organism and succeeded in carrying it back to a morphological stage resembling the culture in which it had originally arisen. The proof of its genetic connection with *Corynebact. diphtheriae* was complete neither in Cache's nor in Spirig's work, and their statements seem therefore to have received little attention, and have remained unconfirmed. Since these organisms grew for many generations as actinomycetes, they were obviously different from the filamentous, branching forms occasionally seen in old cultures of *Corynebact. diphtheriae*. Abbott and Gildersleeve (1904) found these forms occurring so rarely and inconstantly that they considered it justifiable to regard them as "involution forms", and Martin, Loiseau and Gidon (1924) were able to produce them experimentally in great abundance in one particular strain of *Corynebact. diphtheriae* by growth in broth under reduced oxygen tension; when transferred to serum, they reverted at once to the normal type; a hereditary change had thus not taken place here. This seems to occur in *Corynebact. murisepticum* (Holzhausen, 1926), which can appear either as short rods or as long filaments; these characters remain constant on agar media, but tend to revert into each other in broth culture.* Brulowa (cit. by Kedrowsky, 1928) is said to have transformed *Corynebact. diphtheriae* into an actinomyces-like organism by treatment with radium rays. Finally, a dissociation into "smooth" and "rough" variants, not connected with profound morphological changes, has been observed in *Corynebact. diphtheriae* (see Arkwright, 1930). In other corynebacteria, complex life-cycles have been described by de Negri (1916) and Mellon (1920, 1926); the latter author claims to have stabilized several stages of this cycle. Gildemeister (1921) found in the organism of tuberculosis in turtles (*Mycobact. chelonei*) a dissociation into two varieties, the "normal" forming flat, dry colonies with a rough surface, and constantly splitting off the "variant", which forms soft, raised colonies with a smooth surface; this latter kept fairly constant, but showed a reversion to the "normal" in subcultures from very old broth cultures. Vaudremer (1921) found that certain strains of *Mycobact. tuberculosis* lost their acid-fastness when grown on dextrose-agar or agar without glycerin; after having undergone this treatment they produced actinomyces-like forms when grown in peptone-solution; the original form could be regenerated by culture on serum-containing media or on glycerinated potatoes. Kedrowsky (1928) claims to have stabilized an actinomyces-like phase of growth in *Mycobact. tuberculosis* as well as in *Myc. leprae* (see below), and the same statement concerning the former organism is made by Karwacki (1929). It has been known for a long time that *Myc. lacticola* exhibits two cultural varieties, *α planum* and *β perrugosum*. Haag (1927) showed, on the basis of a study of a large number of strains, that these two forms show many intergradations, and that the "perrugose" variety can be transformed experi-

* It may be questionable, however, whether this is really a Corynebacterium.

mentally into the "plane" by growth on agar with addition of old cultures (accumulation of metabolic products). Also spontaneous, mutation-like changes took place. Two strains of the "plane" variety produced secondary colonies of a type described as *Mycobact. eos* (Büttner, 1926), and a case was observed, where a perrugose strain spontaneously produced a plane variant. *Myc. phlei* had likewise a perrugose and a plane form, the latter sometimes being produced by dissociation from the former. One case of variation is particularly interesting, since it seems to represent the origin of an actinomyces as a variant from a mycobacterium. Unfortunately, Haag's description of the phenomenon is very brief, and runs thus: "Merkwürdig verhält sich Stamm 73, welcher zunächst als *Mycobact. phlei* festgestellt war, dann unter Abspaltung eines *phlei*-Stammes (73a) braungelb, matt, körnig und knorpelig wurde, also aktinomyzetenähnliches Wachstum annahm". The existence of an actinomyces-stage in the life-cycle of *Mycobact. leprae* has frequently been alleged. Deycke and Reschad (1905) isolated from a leprome an actinomyces which they believed to be genetically connected with *Myc. leprae*. Kedrowsky (1910) obtained similar results and stated that an organism, isolated from leprous lesions and capable of producing morbid affections in rabbits, had a complex life-cycle comprising acid-fast rods, non-acid-fast rods, and non-acid-fast actinomyces-forms. Similar results have been found by Bayon (1912), Johnston (1917), and others. Duval and Harris (1913) found *Myc. leprae* constantly acid-fast, and believed the aberrant forms to be contaminations. Recently Kedrowsky (1928) has reviewed the question in an interesting paper in which he states that subcultures from very old cultures of *Myc. leprae* and *tuberculosis* are rich in long, branched elements which have partly lost their acid-fastness; by further culture in rich media they soon regain their normal appearance and acid-fastness, but in media poor in nutrients, regular actinomycetes arise as fringes around the colonies. Kedrowsky argues, therefore, that both *Myc. leprae* and *Myc. tuberculosis* should be classed with the genus *Actinomyces*. In this last genus, which is notorious for the instability of its characters, the observations concerning hereditary variation are numerous. Pellegrino (1906) claimed to have transformed an actinomyces into a mycobacterium-like organism by culture in sterile butter; the actinomyces-form could be regenerated by culture on potato. Souza-Araujo (1929) reported a similar case: a true actinomyces isolated from leprous lesions could by culture on fat-containing media be transformed into acid-fast rods, said to be constant. Kedrowsky (1928) mentions the possibility of transforming actinomycetes into diphtheroid organisms by culture in media very rich in nutrients, and Sanfelice (1921, 1924) claims to have transformed two different actinomycetes into *Myc. tuberculosis*-like organisms through animal-passage. Lieske (1921) mentions several cases of mutation-like phenomena in actinomycetes—loss of spore formation, changes in pigmentation, etc. Among other things he (like Ørskov, 1923) observed a formation of a yellow variant from the normally red *Act. polychromogenes*, and a gradual transformation of an anaerobic, short-hyphed form into an aerobic, long-hyphed form. Finally, Ørskov (1923) observed cases where actinomycetes gradually abandoned their mycelial growth and passed into stages where they were indistinguishable from corynebacteria or mycobacteria. A similar case was observed by Abramow (1912) in an actinomyces isolated from meningitic pus; it produced (*a*) branching rods of a diphtheroid type and (*b*) long, richly branching filaments, which formed dry colonies, adhering to the substratum; this latter type changed into the former after a few transfers.

Morphological and Cultural Characters.

As mentioned above, two strains of organisms were isolated from two different soils. They are here termed I and II, the affixes R and F signifying, respectively, the original rod-shaped, mycobacterium-like form, and the modified, filamentous, actinomyces-like form. Single-cell cultures of the two R-forms were obtained by means of the method of Ørskov (1922), and these cultures were examined on the following media:

Dextrose-asparagine-agar: Dextrose 10·0 gm.; asparagine 1·0 gm.; K_2HPO_4 0·5 gm.; agar 15·0 gm.; H_2O 1,000 c.c.

Dextrose-asparagine-solution: Same without agar.

Dextrose-nutrient-agar: Dextrose 10·0 gm.; meat extract 5·0 gm.; peptone 10·0 gm.; NaCl 5·0 gm.; agar 15·0 gm.; H_2O 1,000 c.c. pH 7·0.

Dextrose-broth: Same without agar.

Plain nutrient agar and broth: Same two media without dextrose.

Gelatin: Plain (15% gelatin in tap water) or corresponding to nutrient agar; pH 7·0.

Potato plugs.

Milk.

Cultures were incubated at 30–32° C. and at room temperature (20–22° C.).

During the course of the investigation, several modified types, besides the F-forms, were isolated. A list of these is given below.

Designation.	*Appearance.*	*How obtained.*
Original forms:		
IRs	Rod-shaped, producing soft red growth.	From single cells of original cultures isolated from soil.
IIRs	Rod-shaped, producing soft red growth.	
Modified forms:		
IRh	Rod-shaped with tendency to filament-formation, producing hard pink growth.	Arises spontaneously in cultures of IRs, and can be produced experimentally.
IRy	Rod-shaped, producing soft yellow growth.	Produced by exposure of IRs to ultra-violet radiation.
IRw	Rod-shaped, producing soft white growth.	
IIRh	Rod-shaped, producing hard pink growth.	Arises spontaneously in cultures of IIRs, and can be produced experimentally.
IF	Filamentous, producing firm pink growth with aerial mycelium.	Arises spontaneously in cultures of IRs.
IFy	Filamentous, producing firm yellow growth with aerial mycelium.	Arises spontaneously in cultures of IRy.
IFw	Filamentous, producing firm white growth with aerial mycelium.	Arises spontaneously in cultures of IRw.
IIF	Filamentous, producing firm pink growth with aerial mycelium.	Arises spontaneously in cultures of IIRs.

Form IRs.

Dextrose-asparagine-agar: At room temperature the growth on agar slopes is restricted, raised, with smooth, shiny surface and flat myceloid edges, colour* after 15 days Begonia Rose to Rose Doree (Rdg. I, 1b–I, 3O–Rb). The consistency is after 3–4 days very soft and moist, after 1–2 weeks tough and pasty. Small specks of white aerial mycelium are usually seen after 2–4 weeks; they represent the beginning of the IF-form. Occasionally hard granules of the type IRh appear, and the culture may on transfer change as a whole to this type. At 30–32° C. the growth has a rugose surface and a paler pink colour, after 3–4 weeks changing to dull brownish-grey, with some soluble pigment of the same colour.

Dextrose-asparagine-solution: At room temperature or at 30–32° C. growth starts as small pale-rose flakes in the solution; after 12–15 days voluminous pink sediment and soft, silky, pale-rose surface pellicle; after 20 days at room temperature the pellicle is very thick, soft, colour as on agar.

Dextrose-nutrient-agar: Growth at room temperature is abundant, raised, restricted, after 3–4 days soft and smooth, with myceloid edges, after 1–2 weeks with coarsely folded surface; colour after 16 days Coral Red (Rdg. XIII, 5'OOR). Light-brownish soluble pigment and a few colonies of IF are seen after 3 weeks. Similar growth at 30–32° C.; the F-form is not observed here.

Nutrient agar: Scant, uncharacteristic growth, restricted, orange-red. No pigment. The F-form arises in old cultures.

Dextrose-broth: After 3–4 days slight turbidity, small orange flakes on bottom of tube; after 2–3 weeks orange flaky sediment, no surface growth; broth clear, becomes turbid when shaken. Thick red surface pellicle in older cultures. No acid-formation.

Gelatin (plain or nutrient, at room temperature): Thin yellowish growth along stab, with short filaments radiating into gelatin; flat, red, wrinkled surface-colony. No pigment. No liquefaction after 6–8 weeks.

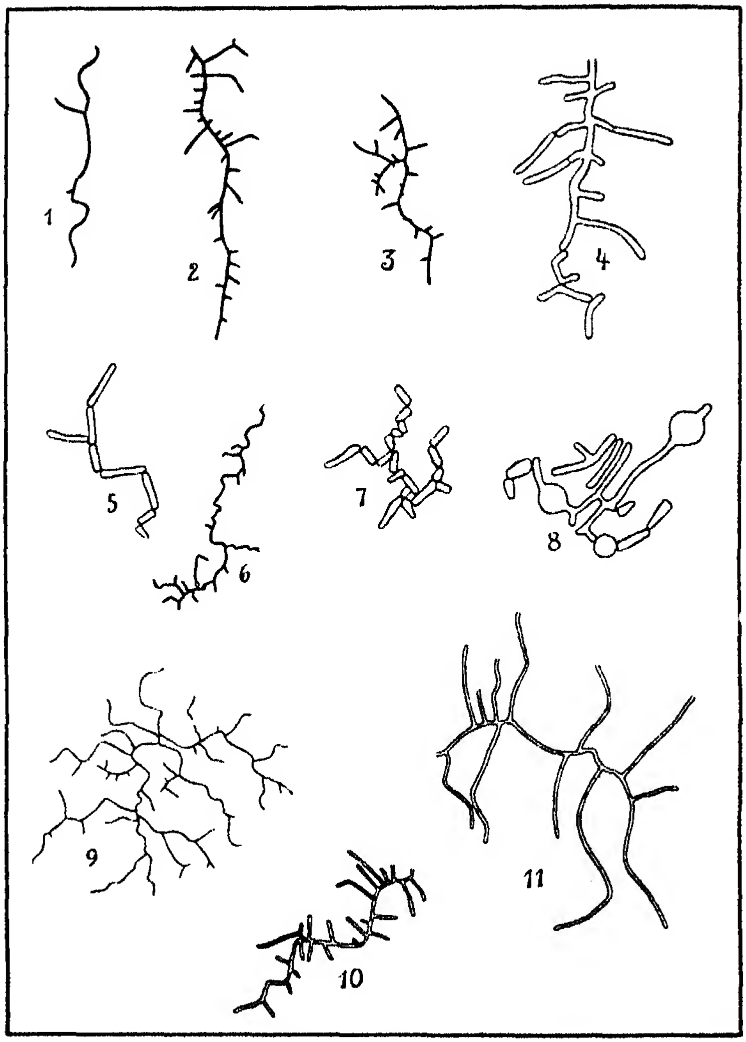
Potato: At room temperature after 3–4 days smooth, soft, pink growth, gradually becoming deeper red and wrinkled. After 2–3 weeks numerous spots of white aerial mycelium (IF), and sometimes raised, hard, pale-pink granules of the type IRh. At 30–32° C. similar, but the spots of aerial mycelium seem to arise less frequently.

Milk: Growth starts as small orange granules on surface; after 1–2 weeks they fall to the bottom and form a thick, soft, orange-red sediment. The milk is not coagulated or hydrolyzed; in quite old cultures (10–12 weeks at room temperature) it becomes viscous and semi-transparent.

Morphology.—Direct observation of the growth (Ørskov, 1923) on blocks of dextrose-agar shows the following mode of development. After 20–24 hours at room temperature the cells of the inoculum have germinated and formed a small mycelium of fairly long, wavy hyphae, 0·4–0·5 μ thick, extending to a length of 70–100 μ, and producing a few side branches (Text-fig. 1). After 2 days these mycelia reach a considerable extent; hyphae produce numerous rectangularly situated side branches, and show some tendency to penetrate into the medium. Aerial hyphae are formed (only visible under the microscope), arising as small refractive granules in the substratum mycelium, and gradually stretching into short, somewhat irregular threads; when examined under immersion lenses, these

* Description of colours here and in the following after Ridgeway, Colour Standards and Nomenclature.

aerial hyphae are not different from the substratum hyphae. Septa are not visible in the substratum mycelium, and the culture makes at this stage a perfectly actinomyces-like impression (Text-fig. 2-3). When the growth is scraped off and examined in ordinary smear-preparations, only slender, branching rods of varying



Text-figures 1-11.

1.—IRs. Dextrose-asparagine-agar, 1 d. room tpt. (living material). 2.—Same, 2 d. 3.—Same, seen under high-power dry lens; aerial hyphae deeply shaded. 4.—Same, 3 d. Immersion lens. 5.—IRh. Dextrose-nutrient-agar, 3 d. room typt. 6.—IRs. Dextrose-asparagine-agar, 5 days room tpt. 7.—Same, 6 d. 8.—Same, potato-extract-agar, 5 d. 32° C. 9.—IF, Dextrose-asparagine-agar, 2 days room tpt. 10.—Same, 3 d., seen under high-power dry lens; aerial hyphae heavily shaded. 11.—Same, under immersion lens. Magnifications: Figs. 1, 2, 3 and 6, × 500; Figs. 4, 5, 7 and 8, × 2,000; Fig. 9, × 250; Figs. 10 and 11, × 1,000.

length, 4–10 × 0·3–0·5 μ, are seen (Plate iii, fig. 3); in carefully made impression-preparations one may occasionally see the true mycelia, but mostly only irregularly staining rods, often in V- or Y-shaped arrangement. After 3 days the organism passes into another stage of growth. Septa are now formed in the substratum mycelium (Text-fig. 4), cutting off rod-shaped cells which occupy an angular position, adjoining each other at the corners like diphtheroids. In the following days this process of septation and of multiplication by cell-division goes on (Text-figs. 6–7). After 6 days all mycelial growth has disappeared.* After 14 days the appearance is unaltered; the colonies consist exclusively of short, unbranched cells, 0·5–0·6 × 1·5–2·0 μ, always in angular arrangement (Plate iii, fig. 4); in still older cultures almost coccoid cells are formed (Plate iii, figs. 5, 6, 9). Thus, the mycelial growth, with which the development of the colony starts, is after a few days superseded by cell-division of the "snapping" type characteristic of corynebacteria (Graham-Smith, 1907); there is never any indication of the "slipping" or "gliding" growth which characterizes *Myc. tuberculosis* (Miehe, 1910) and several saprophytic mycobacteria (Haag, 1927). The aerial hyphae disappear after some days; they appear to fall down and become indistinguishable from the substratum hyphae. The course of development is entirely characteristic for actinomycetes of Ørskov's Group II (Ørskov, 1923).

The cells are gram-positive, but usually stain rather irregularly with anilin dyes, appearing banded and granulated, like many corynebacteria and mycobacteria (Plate iii, fig. 4). They exhibit a certain degree of acid-fastness; after staining with hot carbol-fuchsin most cells are strongly decolourized by 20% sulphuric acid, but a certain number of them retain the stain very well; this is particularly true in old cultures (Plate iii, fig. 9). On other media the appearance of the cells is similar; there is a tendency to earlier production of short, coccoid cells in rich media, such as dextrose-nutrient-agar. At 30–32° C. there is in all media a tendency to production of longer cells than at room temperature; after a few days the culture contains many swollen, fusiform to lemon-shaped cells (Plate iii, fig. 10); they are most numerous on dextrose-nutrient-agar and potato, and particularly on dextrose-asparagine-solution of pH 8·3, where the microscopic appearance often resembles a minute yeast (at pH 5·3–5·7 there is a production of longer, branched, partly swollen cells). The formation of these swollen cells is easily followed on potato-extract-agar, where they arise in great abundance; after 1–2 days there is formed the usual rectangularly branched mycelium, which after 3–4 days divides into rod-shaped cells of varying length; after 4–5 days these cells show local swellings, often measuring 2·0–2·7 μ in diameter (Text-fig. 8). The swollen cells are viable; when transferred to fresh agar, they germinate readily with the formation of a normal mycelium. Similar forms have been described in corynebacteria, mycobacteria and actinomycetes by several authors. Vallée (1903) mentions "des éléments fusiformes, dont la partie seule se colore bien" in *Actinomyces polychromogenes*, and of the same organism Lieske (1921) gives illustrations (Fig. 35, p. 64) which could very well represent the present one. Korn (1908) describes similar formations, resembling heads of spermatozoa or fragments of shattered actinomyces-granules, in *Mycobact. friburgense*. Identical-looking phenomena are described by Vierling (1922) as "involution forms" in cultures of soil mycobacteria (or actinomycetes?). Ørskov

* On the surface of the agar; in the depth the development is difficult to follow, but septation seems to take place here, too.

(1923) found a general tendency to production of such forms in a whole category of actinomycetes, and Henry (1910) found them arising in cultures of an anaerobic actinomyces when exposed to the air. Finally, Bergstrand (1923) describes similar forms under the name of "chlamydospores" in *Corynebact. lymphogranulomatis*; they show, according to his figures, a mode of formation analogous to that in our IRs, but his statement, that they multiply by yeast-like budding, suggests that they may, at least partly, be of another nature. Apparently these swollen cells represent nothing but a strongly accentuated development of the club-shaped cells often observed in corynebacteria and mycobacteria, but they are probably of another nature than the yeast-like cells described below under IIRs. The regularity of their appearance and their vitality render it unjustifiable to dispose of them as "involution forms", and their germination into a mycelium does not support the theory that they may be gonidangia. Further, their mode of formation inside a single cell shows that they are not "zygospores" arising through conjugation of two cells (Löhnis and Smith, 1923).

Form IRh ("hard" type of IRs).

Dextrose-asparagine-agar: Growth at room temperature after 3–4 days thin, flat, almost colourless, with some raised pink granules of hard consistency. After 1–2 weeks the growth is abundant, much raised and wrinkled, adhering strongly to the medium, surface cracking; consistency hard, dry and crumbly, but not cartilaginous like a true actinomyces; colour after 15 days Alizarin Pink to Venetian Pink (Rdg. XIII, 1'd.–XIII, 1'f.), paler than IRs. A faint pinkish-grey soluble pigment is formed after 3 weeks. At 30–32° C. similar, growth more dirty pinkish-grey; scant white aerial mycelium may be seen, but the F-form does not arise.

Dextrose-asparagine-solution: Growth as hard granules on bottom and along surface of solution; tendency to formation of a tough, granulated, pink surface pellicle.

Dextrose-nutrient-agar: Growth at room temperature abundant, much raised and granulated, of a crumbly consistency, but not so hard as on dextrose-asparagine-agar; colour after 15 days Carnelia Red (Rdg. XIV, 7'R-O). Light-brown soluble pigment after 2–3 weeks. Growth at 30–32° C. similar, but of softer consistency.

Nutrient agar: Scant, uncharacteristic growth, granulated, orange-red.

Dextrose-broth: Broth clear with granulated orange sediment; no surface growth; no uniform turbidity when the tube is shaken. No acid-formation.

Gelatin: = IRs.

Potato: Growth starts at room temperature as orange-red, raised, firm granules, gradually spreading after 1–2 weeks, becoming deeper red; consistency partly crumbly, partly soft after 3 weeks. No aerial mycelium. At 30–32° C. similar growth, deeper red.

Milk: Orange granules on surface. Milk somewhat thickened after 3–4 weeks at 30–32° C.

The F-form has never been seen to arise in cultures of this type.

Morphology.—The growth on dextrose-asparagine-agar starts in the same manner as IRs, but there is a much more pronounced tendency to growth in the

depth of the medium, and much less tendency to septation. After 14 days at room temperature the elements are still chiefly filamentous and non-septate, only here and there showing rod-shaped cells in angular arrangement. On dextrose-nutrient-agar septation sets in after 3 days at room temperature, and the culture appears here much like IRs, although the cells are generally longer and more slender, 2·0–8 × 0·4–0·5 μ (Text-fig. 5). In smear preparations, especially from dextrose-asparagine-agar or solution, the long, non-septate filaments are very frequently seen, but they seem very easily to be broken up by rough treatment of the material (Plate iii, fig. 2). The rod-shaped cells are always longer, more slender and more irregular in shape than those of IRs. They are also less acid-fast; none of them retains the dye perfectly, but they show a number of acid-fast granules. At 30–32° C. swollen cells, similar to those of IRs, are formed.

Form IRy (yellow modification of IRs).

Dextrose-asparagine-agar: Growth at room temperature restricted, raised, with smooth, shiny surface and flat, myceloid edges; consistency soft and moist, pasty. Colour after 16 days Ochraceous Salmon to Flesh-Ochre (Rdg. XV, 13'OYO-XIV, 9'OR-Ob).

Dextrose-asparagine-solution: At room temperature a thick soft pellicle of same colour as on agar, and thick yellow sediment. Solution clear, becomes turbid on shaking.

Dextrose-nutrient-agar: Good growth at room temperature, raised, soft, smooth, with myceloid edges; colour after 16 days Apricot Orange (Rdg. XIV, 11'). Growth somewhat granulated and folded after 3 weeks, with a faint brown soluble pigment.

Dextrose-broth: Broth slightly turbid after 4 days at room temperature, with yellow flakes on bottom. After 1–2 weeks thick yellow sediment, no surface growth; broth almost clear, turbid when shaken. Yellow pellicle in older cultures.

Gelatin: Scant yellow growth along stab and on surface; short filaments radiating from stab; no liquefaction.

Potato: Soft, smooth, raised, yellow-ochre growth after 4 days at room temperature. After 2–3 weeks numerous hard granules with white aerial mycelium arise, representing the form IFy.

Milk: Growth starts as small loose yellow flakes along the wall of the tube, after 7–8 days settling and forming a soft yellow sediment; milk unchanged after 4 weeks at room temperature.

Morphology.—This organism corresponds in morphological respect perfectly to IRs, but the formation of a "hard" variant, corresponding to IRh, has not been observed.

Form IRw (white modification of IRs).

Dextrose-asparagine-agar: Good growth at room temperature, raised surface, first smooth, later roundly-folded, edges slightly myceloid; consistency soft and pasty; colour milk-white. After 4–5 weeks a faint pink colour develops, but platings show only white colonies.

Dextrose-asparagine-solution: Thick, soft, white pellicle and sediment after 3 weeks at room temperature; solution clear, becomes turbid when shaken.

Dextrose-nutrient-agar: Growth similar to that on dextrose-asparagine-agar, but surface after 10–12 days more wrinkled and granulated on central part, edges entire. Faint brown pigment after 2–3 weeks.

Dextrose-broth: Slight turbidity after 4 days, white flaky sediment. After 2 weeks abundant white sediment and broken white scum on surface. Broth clear, turbid when shaken. No acid after 3 weeks.

Potato: Scant, smooth, raised, white growth after 4 days at room temperature. After 1–2 weeks growth somewhat better, with folded surface, else unchanged. Small specks of white aerial mycelium (Fw) arise after 3 weeks.

Gelatin: Thin white growth along stab, with short, horizontally radiating threads. White surface growth. No liquefaction.

Milk: Growth starts as small white flakes along wall of tube, later (1–2 weeks) forming a white sediment. Milk unchanged.

Morphology.—Exactly like IRs and IRy. These three forms are distinguished from each other practically only by the pigmentation; the formation of the yellow and the white variety from the original red seems analogous to the well-known production of a lemon-yellow and a white variety (known respectively as *Staphylococcus citreus* syn. *Micrococcus pyogenes β citreus*, and *Staphylococcus albus* syn. *Micr. pyogenes γ albus*) from the orange *Staph. aureus* syn. *Micr. pyogenes α aureus* (Neumann, 1897), only in the staphylococci these phenomena occur spontaneously, while in the present instance they were only observed after treatment with ultraviolet rays.

Form IIRs.

Dextrose-asparagine-agar: Growth after 6 days at room temperature restricted, raised, with rugose surface and myceloid edges, consistency soft and moist. After 2 weeks the growth is abundant, surface much wrinkled, consistency tough-pasty, colour like IRs. Specks of white aerial mycelium (IIF) arise after 3–4 weeks, sometimes earlier. At 30–32° C. the growth is paler pink, after 3 weeks dirty pinkish-grey, with some soluble pigment of the same colour.

Dextrose-asparagine-solution: Soft, silky, pink pellicle and sediment; solution clear.

Dextrose-nutrient-agar: After 1 week at room temperature similar to dextrose-asparagine-agar, but better growth, of a deeper red colour. After 15 days abundant, much raised and folded, Grenadine Red to Flame Scarlet (Rdg. II, 7R-O–9OR-O). Faint brown soluble pigment after 3 weeks. At 30–32° C. the growth is hardly different, develops somewhat more rapidly.

Dextrose-broth: Flaky orange sediment after 1 week at room temperature: similar, more voluminous, after 2–3 weeks. Broth clear, only occasionally with granules of surface growth. At 30–32° C. similar growth. No acid is formed. Thick red surface pellicle in older cultures.

Gelatin: At room temperature, 3–5 weeks, filiform growth along stab, with short radiating threads, and wrinkled red surface growth. No liquefaction.

Potato: After 1 week at room temperature soft, moist, glistening, red growth; after 2 weeks round-granulated surface, pasty consistency, intense red colour. Numerous specks of white aerial mycelium (IIF).

Milk: Small reddish flakes swimming on surface and attached to the tube after 3–6 days; after 2–3 weeks a flaky, red sediment is formed. Milk remains unchanged.

Morphology.—The development on dextrose-asparagine-agar takes place in the same manner as in IRs. The rod-shaped cells are generally somewhat longer and more slender and show less tendency to production of swollen, lemon-shaped forms at 30–32° C., particularly in dextrose-asparagine-solution, where the shape of the cells is little influenced by the reaction, unlike IRs. The cells are also less acid-fast than those of IRs; on dextrose-asparagine-agar there is almost no acid-fastness, but on dextrose-nutrient-agar this strain is like IRs. In dextrose-broth (to a smaller extent also on dextrose-nutrient-agar) there is frequently after 4–6 days at 30° C. a formation of remarkable, big, oval, yeast-like cells, measuring 4–5 μ, usually aggregated in small clumps, containing a coarsely granulated cytoplasm, and staining intensely with carbol fuchsin and Delafield's haematoxylin (Plate iii, figs. 7, 8). They seem to correspond to similar phenomena observed in corynebacteria by de Negri (1916), Mellon (1920), and Bergstrand (1922), and in actinomycetes by Leyton and Leyton (1916), who call them "megaspores". Similar things have been described as "gonidangia" in other bacteria by Löhnis and Smith (1923), Oesterle and Stahl (1929), Gibson (1928), and several others.* The gonidangium-nature of the present cells is uncertain, since it has not been found possible to follow their further development when transferred to fresh media; in hanging agar-block preparations they remain unchanged for up to 10–12 days, while the normal rod-shaped cells multiply vigorously. Neither have they shown any development in hanging-drop preparations (dextrose-broth) for up to 3 days. In preparations from broth-cultures these cells often show evidence of a reproduction by yeast-like budding (Plate iii, fig. 8), as described by Bergstrand (1923), whose "chlamydospores", however, seem partly identical with the swollen forms in our IRs. These latter are different from the yeast-like cells, since they, as stated above, germinate readily on agar media. The true nature of the yeast-like cells must, therefore, for the present, be regarded as unknown. Besides these there is often after 5–6 days in broth cultures a quite abundant formation of clumps of amorphous, granulated matter, resembling the phenomenon described as formation of "bacterial plasmodia" (Almquist, 1917) or "symplasm" (Löhnis, 1921, Löhnis and Smith, 1923). These flakes of amorphous material can quite easily be traced in hanging-agar-block preparations, like the yeast-shaped cells, and like these they remain unchanged for many days, until they are overgrown by colonies originating from neighbouring normal cells. A regeneration of cells inside them has never been observed, and there is thus so far no evidence that they represent living matter (cf. Bergstrand, 1923).

Form IIRh ("hard" type of IIRs).

Dextrose-asparagine-agar: Growth after 6 days at room temperature much raised and wrinkled, pale rose-pink, of a dry and crumbly consistency, somewhat adhering to the agar, after 12–15 days still more wrinkled. Colour Eosine Rose to Begonia Pink (Rdg. I, 1d–I, 1b). The aerial mycelium is often macroscopically visible as a thin white veil all over the growth.

Dextrose-nutrient-agar: Growth after 6 days at room temperature similar to dextrose-asparagine-agar, but more red; after 12–15 days abundant, much

* The *Schizosaccharomyces filtrans* described by Lewis (1927) is probably also an organism of this group, and no yeast at all.

folded, of a somewhat pasty consistency; colour Light Coral Red (Rdg. XIII, 5'OO-Rb). Light-brown soluble pigment after 3 weeks.

Dextrose-broth: Abundant growth after 3 weeks at room temperature; granulated red sediment and thick, easily broken, red pellicle. No acid.

Potato: Growth at room temperature first granulated, pale-orange, of a firm consistency, after 3–4 weeks dull red with thin veil of white aerial mycelium on upper dry part.

Milk: Small red granules on surface, partly falling to the bottom. Milk unchanged after 4 weeks.

At 30–32° C. the cultures are hardly distinguishable from IIRs.

As in the case of IRh, an F-form has not been seen to arise.

Morphology.—Microscopically this strain can hardly be distinguished from IIRs, except for the more pronounced tendency to formation of aerial hyphae.

Form IF (filamentous form of IRs).

Dextrose-asparagine-agar: Growth at room temperature after 5 days consists of small, round, raised, partly confluent, pale-pink granules with myceloid edges, growing deeply into the agar and covered by a thin white aerial mycelium. After 12–15 days a granulated, confluent growth of a tough, cartilaginous, entirely actinomyces-like character, adhering strongly to the medium; colour Orient Pink (Rdg. II, 9 OR-Of). Similar at 30° C. The aerial mycelium is rather variable on this medium, sometimes almost absent, sometimes, particularly at room temperature, forming a well-developed, white, felty layer. The consistency remains cartilaginous in very old cultures (5–6 months).

Dextrose-asparagine-solution: Growth starts as small colourless granules on surface and bottom of solution, after 12–15 days, forming a thick, granulated, pale rose pellicle. Solution remains perfectly clear.

Dextrose-nutrient-agar: After 5 days at room temperature small pinkish-orange granules without aerial mycelium; after 12–15 days raised, round, partly confluent granules, with scant white aerial mycelium; consistency hard and cartilaginous; colour Grenadine Pink (Rdg. II, 7R-Od). Faint brown soluble pigment. Similar growth at 30° C.; after 3–4 weeks the central superficial part of the growth assumes a more loose and crumbly consistency.

Dextrose-broth: Small pink granules on surface, after 12 days at room temperature forming a coherent, pale-pink pellicle with thin white aerial mycelium. Broth remains perfectly clear. No acid is formed.

Gelatin: Scant filiform growth with short radiating threads along stab; rose-red surface colony with thin white aerial mycelium; no liquefaction.

Potato: Growth spreading, granulated, pink, after 12 days covered by a thin white aerial mycelium; consistency hard and cartilaginous, after 5–6 weeks at 30° C. brittle and crumbly in dried part of growth.

Milk: Small pale-pink granules on surface, gradually forming a red pellicle with thin white aerial mycelium. Milk remains unchanged.

Morphology.—The growth on dextrose-asparagine-agar starts in a manner similar to that of IRs. After 2 days at room temperature extensive mycelia are formed, measuring 100–150 μ across, consisting of richly branched hyphae with numerous aerial filaments and a marked tendency to growth in the depth of the agar; the central filaments are thicker (up to 0·8–0·9 μ) than the end

branches (0·4–0·5 μ). After 3 days the mycelia reach a very large extent and exhibit all the characters of a true actinomyces of Group I (Ørskov, 1923). In the following time the organism seems to remain at this stage of development (Text-figs. 9–11); unlike IRs, an angular arrangement is not seen, the hyphae remaining wavy and irregularly branching; septa are not formed. In the aerial hyphae a differentiation into spores, such as in Ørskov's Group I, is not seen, but when the aerial mycelium is scraped off and examined in ordinary preparations, the hyphae are easily broken into fragments of varying length, down to 5–6 μ long and 0·4–0·5 μ thick. Ordinary stained preparations show a typical actinomyces-mycelium: long, slender, branching filaments, mostly 0·4–0·5, up to 0·8–1·0 μ thick, staining rather irregularly with anilin dyes (Plate iii, fig. 1). The hyphae are gram-positive, but only slightly acid-fast; like IRh, they are mostly decolourized by 20% sulphuric acid, but show numerous acid-fast granules. The loose and crumbly growth in old cultures on dextrose-nutrient-agar and potato shows microscopically many rather short, irregular, branching rods, somewhat similar to IRh, and quite markedly acid-fast; a similar phenomenon is seen in dextrose-asparagine-solution of pH 8·3 after 3 weeks at room temperature. This, however, does not represent a reversion to the R-form, since these cells produce only the normal F-form when transferred to fresh medium. In dextrose-asparagine-solution of pH 8·3 there is also, previous to the formation of short forms, a production of remarkably curved and gnarled filaments with many short lateral branches bearing terminal swellings which stain intensely and give the organism a *Micromonospora*-like appearance (Ørskov, 1923; Jensen, 1930).

Forms IFy (filamentous form of IRy) and IFw (filamentous form of IRw).

These two organisms are parallel forms to IF, from which they differ only in colour.

Form IIF (filamentous form of IIRs).

Culturally this form is very similar to IF, from which it differs mainly in a more pronounced tendency to formation of aerial mycelium, particularly at room temperature, and in its colour. The growth on dextrose-asparagine-agar after 12–15 days is at room temperature Grenadine Pink (Rdg. II, 7R-Od), at 30° C. Pale Salmon to Seashell Pink (Rdg. XIV, 9'f–11'f), on dextrose-nutrient-agar at room temperature Grenadine Pink, at 30° C. Brazil Red (Rdg. I, 5i). Morphologically it is indistinguishable from IF.

Biological Characters.

So far as studied, the various forms seem identical in physiological respect, although a complete study of their physiology has not been carried out. They are all obligate aerobic organisms. Invertase, diastase and proteolytic ectoenzymes are not produced. Paraffin wax, benzene vapour, stearic acid, phenol, and cellulose are not utilized. The optimal temperature seems to be 25–30° C.; at 60° C. the cells are killed within 2 minutes; aerial mycelium of IF shows no higher thermoresistance than the substratum mycelium. The optimal reaction is at approximately neutral reaction. IRs, IIRs, IF and IIF were grown in dextrose-asparagine-solution, the reaction of which was adjusted to pH values between 5·0 and 8·3 by means of tartaric acid and sodium hydroxide. The following results were found after 12 days at 30° C.:

pH	Growth of			
	IRs	IIRs	IF	IIF
5·2	none	none	none	none
5·7	trace	trace	very scant	trace
5·9	very good	fair	fair	scant
6·5	excellent	good	good	fair
6·8	excellent	good	very good	fair
8·3	fair	scant	good	scant

Identity of the Organism.

The two original forms, IRs and IIRs, particularly the former, are doubtlessly identifiable with *Actinomyces polychromogenes* Vallée. The original description of this organism (Vallée, 1903) is not very complete, but it agrees with the present in the formation of long branching filaments in quite young cultures, short oval rods after a few days, fusiform cells in acid solution, and pigment of various red colours. Lieske (1921) and Ørskov (1923) have studied the same organism. Both authors record a spontaneous formation of a yellow variant, corresponding to our IRy. Their microscopic illustrations of *Act. polychromogenes* resemble the present organisms perfectly; Lieske's Figs. 24, 25, 26 and 35, and Ørskov's Figs. 40 and 42 could very well represent our IRs. Lieske also found *Act. polychromogenes* acid-fast under certain conditions. Neither Lieske nor Ørskov found, in disagreement with Vallée, any formation of aerial mycelium; this property had apparently been lost in the long period of artificial cultivation between the studies of Vallée (1903) and of Lieske and Ørskov (1921-1923). We may conclude from these data, that *Act. polychromogenes* is a species-group with a pronounced tendency to hereditary variation, some strains (e.g., that studied by Vallée, Lieske and Ørskov) producing yellow variants spontaneously, others (e.g., IRs) producing "hard" and filamentous variants spontaneously, besides white and yellow variants under certain conditions (after treatment with ultraviolet rays, as shown below), and others again (e.g., IIRs) producing only "hard" and filamentous variants spontaneously.

Various Factors that Influence the Appearance of Modified Forms.

Age of Cultures.—As shown above, the F-forms arise mostly in cultures 3-4 weeks old. Subculture on dextrose-asparagine-agar from some older cultures gave the following results:

IRs in dextrose-asparagine-solution, 21 weeks at room temperature: IRh predominant, IF also present.

IRs in milk, 20 weeks at room temperature: same.

IRs in dextrose-broth, 15 weeks at 30° C.: mixture of IRs, IRh, and IF; last form predominant.

IIRs on gelatin, 18 weeks at room temperature: mixture of IIRs and IIRh. On dextrose-asparagine-agar, 20 weeks at room temperature: same.

Ageing of the cultures does thus here, as in many other cases (Arkwright, 1921, 1930), give rise to variation (cf. also Kedrowsky, 1928, and Spirig, 1903).

Drying.—Numerous experiments by Almquist and co-workers (Almquist, 1917; Almquist and Koraen, 1918; Koraen, 1918) suggest that drying of the cultures

may markedly influence the life-cycle of various bacteria. In the present instance, no variation was found in subcultures on dextrose-asparagine-agar from dried-up cultures (4–5 weeks at 30° C.) of IRs and IIRs. Drying does thus not seem to be a special incitant to variation here; this has possibly some connection with the fact that mycobacteria and actinomycetes are as a whole very resistant to drying.

Metabolic Products.—The fact that the F-forms arise in rather old cultures suggests that the accumulation of metabolic products may have something to do with the phenomenon. In order to test this, IRs and IIRs were grown on media which had previously supported growth by the same organisms. Nadson and Adamovič (1910) could in this way induce remarkable morphological changes in *Bac. mycoides*, and Haag (1927) was, as mentioned above, by a similar method able to induce changes in mycobacteria. Other similar cases are quoted by Arkwright (1930).

Two series of experiments were carried out here:

I. Old cultures of the Rs-forms on dextrose asparagine-solution (2 months at room temperature) were boiled and filtered, and 1% dextrose, 1·5% agar and a trace of asparagine were added. IRs and IIRs were then grown on slopes of this medium at room temperature, with transfers every 10 to 14 days. The originally soft and moist growth became, after 2–3 transfers, dry and crumbly, with a wrinkled surface and covered by a thin white aerial mycelium. A complete change into the F-forms was not observed, but subcultures on ordinary dextrose-asparagine-agar from the fifth generation showed that the R-forms, originally of the s-type, had been changed into the h-type.

II. IRs and IIRs were grown in dextrose-peptone-solution (150 c.c. in 350 c.c. Erlenmeyer flasks) for 6 weeks at 30° C. The solutions were then boiled and filtered, and 1% dextrose, 0·5% peptone and 1·5% agar were added. IRs and IIRs were as before grown on slopes of the corresponding agar medium for five generations. IRs produced an abundant, smooth, pasty, red growth, occasionally producing the F-form, and in the fifth generation becoming more dry and crumbly. IIRs produced also an abundant growth, similar in all generations, raised and wrinkled, covered with a veil of aerial mycelium, but of a soft and loose consistency without any trace of the F-form. Transfers to dextrose-asparagine-agar from the fifth generation gave, as before, a growth of the h-types of both R-forms; a transfer from the first generation of IRs gave the normal s-form. Here again a change of the s-types into the h-types has been effected.

Ultraviolet Radiation.—In the experimental study of heredity, much attention has in recent years been paid to the influence of short-wave radiation (ultraviolet radiation and X-rays) on the progeny of irradiated organisms. In microbiology a few cases of hereditary variation due to this cause have been recorded. Henri (1914) exposed *Bac. anthracis* to ultraviolet radiation and obtained in this way three modified forms, two of which proved constant for many generations. Enderlein (1925) states that exposure to sunlight exerts a strong influence on the alleged cyclogeny of *Vibrio cholerae*, giving rise to formation of filterable gonidia and to sexual reproduction. Following up the suggestions of Enderlein, Oesterle and Stahl (1929) were able to produce filterable forms and other aberrant types of *Bac. mycoides* by exposure to sunlight or ultraviolet rays. Nadson and Philippow (1929) induced mutation-like changes in the fungus *Zygorhynchus Moelleri* and in yeasts by treatment with X-rays. The changes mentioned by Brulowa (Kedrowsky, 1928) have been referred to above.

An experiment on the influence of ultraviolet radiation on IRs and IIRs was carried out. Since no quartz-lamp was available, an arc-lamp with iron electrodes, consuming a current of 5·2 Amp., 112 V., was used as source of ultraviolet rays The material to be treated consisted of 1·5 c.c. portions of suspensions of 8 days old dextrose-asparagine-agar cultures in sterile 0·85% NaCl solution, placed in small transparent silica test tubes. These tubes were placed in a distance of 30 cm. from the naked arc, at which distance the heat effect was negligible, and subjected to the radiation for ½, 1, 2, 3, 4 and 6 minutes. After treatment, a loopful of each suspension, as well as of untreated control suspension, was transferred to slants of dextrose-asparagine-agar, and duplicates were incubated at room temperature. The control tubes of IRs showed only the normal IRs. Thirty seconds' irradiation caused a slightly delayed start of the growth, which contained numerous hard granules of the IRh-type. Irradiation for 1 to 6 minutes caused a continually thinner and more slowly starting growth, always consisting of a mixture of the soft, red colonies of IRs and the hard, raised, pale-pink colonies of IRh; most of the tubes also contained a few of the white colonies of IRw, and in one of the tubes from 3 minutes irradiation a colony of IRy appeared. Of the F-form, only a single colony was observed. It was thus possible to produce three modified forms (IRh, IRw, and IRy, although the last was very rare) by treatment of IRs with ultraviolet rays. IIRs produces a similar mixture of IIRs and IIRh, but this experiment was less convincing, since the h-type was present also in the control, although it seemed more abundant in the cultures from irradiated inoculum.

Other Factors.—Addition of 0·1% coffein or 1·0% lithium chloride (compounds which are both capable of exerting a strong formative influence on many bacteria) to dextrose-asparagine-agar had no clear effect on IRs and IIRs. The former compound did not affect the growth visibly, the latter suppressed it almost entirely. Neither did growth for 14 days on a starvation medium (pure agar in tap water) exert any influence on the subsequent growth of IRs, IRh, IIRs and IIRh on dextrose-asparagine-agar.

The experiments thus show that we can in several cases experimentally change the Rs-types into other types, but the appearance of the F-forms seems to occur quite spontaneously and is not influenced by any of the factors tested here.

Discussion.

The question of the nature of these modified forms now suggests itself. The "soft" and "hard" types of the R-forms represent probably cultural varieties analogous to the "plane" and "perrugose" varieties in the closely related mycobacteria; they may possibly also be compared with the "smooth" (S) and "rough" (R) variants of intestinal bacteria (Arkwright, 1921, 1930), though it has not been tested whether they are serologically different from each other. IRy and IRw are obviously colour-varieties of IRs, comparable to those in the staphylococci, as mentioned above. The appearance of the F-forms seems to present a more extraordinary phenomenon. The whole morphological character of the F-forms would lead us to regard them as stabilizations of the initial mycelial stage of the R-forms, but they are apparently not formed directly from these initial mycelia, since they arise only in comparatively old cultures, where all mycelial growth has disappeared long ago. What seems to happen is, that now and again a cell of the R-form reverts to the original actinomyces-like mode of growth and remains at this stage, due to causes which at present we cannot ascertain. The "hard" types

of the R-form (particularly IRh) seem to represent an incomplete step in the direction of the F-form. Whether we should regard the F-forms, which so far have proved constant, as simple hereditary variants or as stages in the life cycle of the organism can only be ascertained when the F-forms have been observed for a very large number of generations, in order to see whether they will again change back into the R-form.

The origin of the F-forms throws an interesting light upon the alleged production of actinomyces-like forms in *Corynebact. diphtheriae* (Cache, Spirig) and *Myc. leprae* and *tuberculosis* (Kedrowsky, and others). When typical actinomycetes (the F-forms) can arise in single-cell cultures of mycobacterium-like organisms (the R-forms), it would seem likely that the same phenomenon might occur in true corynebacteria and mycobacteria, from which our R-forms differ only in the extent of their initial mycelium. This difference is one of degree only, since also corynebacteria and mycobacteria may occasionally show indications of a mycelial growth (Lepeschkin, 1904, Ørskov, 1923, and Haag, 1927; Lepeschkin's *Bacillus Berestnewii*, which showed an hereditary tendency to branching and occasionally to formation of small mycelia, was in all probability a corynebacterium or a non-acid-fast mycobacterium. Haag describes, in his Fig. 2, such a case as "aussergewöhnliche Form").

The phenomenon has also an important bearing on the systematics of the genus *Actinomyces*. Ørskov (1923) suggested a division of this into two genera, primarily on the basis of the formation of septa in the mycelium. The present results show that at least this criterion cannot be used unreservedly, since on the basis of this alone we would have to place the R-forms and the F-forms in two different genera—a procedure which one cannot but feel as unnatural, despite the fact that all classification is artificial and all limits arbitrary. On the other hand, a careful study of phenomena such as these will enable us to place the systematics of the actinomycetes, as well as of other microorganisms, on a firmer and more natural basis than previously (cf. Löhnis and Smith, 1923).

Summary.

Single-cell cultures of two strains of a soil actinomyces, probably identical with *Act. polychromogenes* Vallée, produced two different growth forms. The first and original form "R" (rod-shaped) forms initially a small unicellular mycelium which soon divides into bacteria-like elements; these multiply by cell division in the manner characteristic of corynebacteria. This R-form has two subtypes; the s-type ("soft"), which is the original, produces a soft, pasty growth of a red colour; the bacteria-like elements are usually short, blunt, little branched, and partly acid-fast. The h-type ("hard") produces a dry, crumbly growth, adhering firmly to the medium and consisting of longer and more slender cells, less acid-fast than the s-type and with a marked tendency to formation of long filaments; this type arises spontaneously in cultures of the s-type and can also be produced experimentally from this. Exposure to ultraviolet rays gave rise to a yellow and a white variety of the s-type. The difference between the s- and h-types was more pronounced at room temperature than at 30–32° C. and more pronounced in one strain than in the other. These s- and h-types seem to correspond to the "plane" and "perrugose" variants of mycobacteria, and are possibly also comparable with the "smooth" and "rough" variants known to occur in numerous other bacteria. The second form "F" (filamentous) represents a stabilization of the initial mycelial stage of the R-form. It is a perfectly actinomyces-like organism,

consisting of long, delicate, branching hyphae, with a well-developed aerial mycelium, and without any tendency to divide by septa into bacteria-like elements. It arises spontaneously in old cultures of the R-form of the s-type (not in the h-type), and its appearance does not seem to be influenced by external factors.

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H

EXPLANATION OF PLATE III.

Fig. 1.—IF. Dextrose-asparagine-solution, 9 d. room typt. (Carbol-fuchsin). Fig. 2.—IRh. Dextrose-nutrient-agar, 12 d. room tpt. (Carbol-fuchsin). Fig. 3.—IRs. Dextrose-nutrient-agar, 1 d. room tpt. (Carbol-fuchsin). Fig. 4.—Same. Dextrose-asparagine-agar, 12 d. room tpt. (Carbol-fuchsin). Fig. 5.—Same. Potato, 13 d. room tpt. (Nigrosin). Fig. 6.—IIRs. Gelatin, 32 d. room tpt. (Nigrosin). Figs. 7, 8.—Same. Dextrose-broth, 4 d. 32° C. (Carbol-fuchsin). Fig. 9.—IRs. Dextrose-asparagine-agar, 2 months room tpt. (Hot Carbol-fuchsin, differentiated with 20% H_2SO_4). Fig. 10.—Same. Potato, 13 days 32° C. (Nigrosin).—All photographs are taken with the Zeiss "Phoku" apparatus × Apochr. 1·5 mm. N. Ap. 1·30. Magnifications × 750.

THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. I.

TALLONG–BUNGONIA.

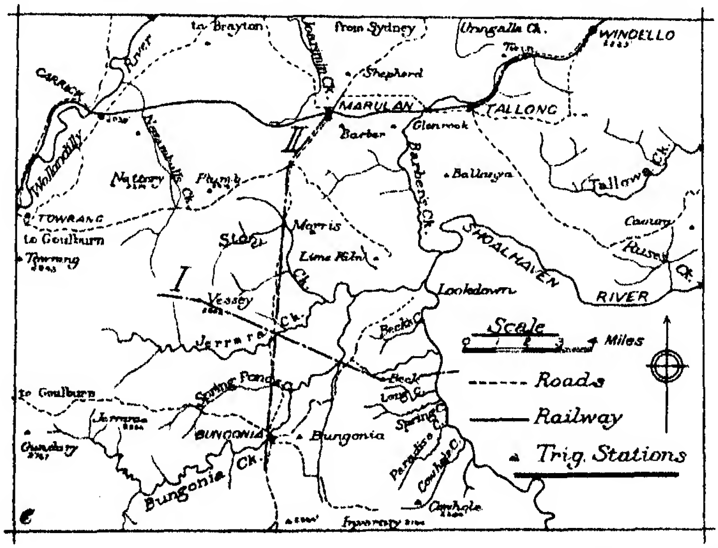
By FRANK A. CRAFT, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(Plates iv–vii; ten Text-figures.)

[Read 29th April, 1931.]

This is the first of a series of papers in which it is proposed to deal with the physiography of the Shoalhaven Valley, from the head of the river to a point some ten miles south-east of Tallong. This area of 2,600 square miles includes much broken and mountainous country which is difficult to traverse, and considerable stretches of level plains. Areas such as that dealt with in the present paper, which are capable of yielding the most valuable information, are to be studied in detail, whilst others will be investigated by more general methods. The actual methods employed depend largely upon the nature of the country involved. Obviously any considerable physiographic survey in mountainous country is not practicable, and the absence of any feature survey over considerable areas of such country is a disadvantage.

The writer wishes to thank the Surveyor-General and Mr. L. H. Bowler of the Lands Department for making maps and survey information available. In field-work, the help and hospitality of Mr. and Mrs. J. G. Hoare and family of Tallong



Text-fig. 1.—Locality Map of the Area. The Main Southern Highway passes through Marulan and Towrang.

have been invaluable. Parts of the work incorporated in this paper have been discussed with Professors Cotton, Browne and Macdonald Holmes, to the latter of whom the inclusion of Text-figure 5 is due.

Unless otherwise stated, all heights quoted are referred to sea-level, and the magnetic meridian is used throughout (declination = 9° 35′ E.).

The Area Dealt With. (Text-figs. 3, 7.)

Between Moss Vale and Goulburn, on the Main Southern Railway of New South Wales, there is an expanse of upland plains, with low ridges and tableland masses rising above the general level. In places the railway passes through fertile basalt country, but the general impression is one of sandy uplands and gentle stream valleys, the latter seeming to wind blindly into low hills. To the south are steep-sided gorges and ravines which have been carved by the Shoalhaven River in the course of its attack upon the highlands. These cannot be seen from the railway, and their presence is only appreciated when, in crossing an apparently unbroken plain, a traveller finds himself on the edge of a precipice with a stream many hundreds of feet below.

In this part the Shoalhaven, previously following a northerly course, turns sharply eastward to enter the sea below Nowra. The outer side of the great elbow bend thus formed consists of the uplands observed from the railway, which continue southward to form extensive plains to the west of the river. The higher points exist because of the resistance which their component material offers to weathering and erosion and, their slopes having been exposed to the weather over great periods of time, their sides are littered with rock debris.

The sides of the modern canyons are still very steep, and they either carry a thin covering of scree or consist of lightly-forested rock slopes. Such complex gorges as those found in the more dissected parts of the Blue Mountain Tableland are absent for, although the stream pattern is intricate, the tributaries have not cut back very far from the main gorge, which has a simple enough appearance when viewed from the uplands.

The country on the concave side of the great elbow presents a very even skyline before the commencement of the eastward coastal fall, but its surface covering of almost horizontal sandstone has favoured the development of precipices along all of the steeper stream courses, making that part very difficult of access. The river has cut it off completely from the railway side, and thus forms an excellent natural boundary for purposes of survey, classification or description.

Previous Literature.—The chief published accounts of this area are those of Andrews (1904), Woolnough and Taylor (1906) and Woolnough (1909). In the second the authors postulate a previous connection between the Upper Shoalhaven and Wollondilly Rivers. This stream line, they state, was finally broken after the period of uplift which formed the modern plateau and allowed the present lower Shoalhaven to cut back and capture the stream which now forms its headwaters. Evidence for the existence of the stream line referred to depends on certain mature valleys, stream gravels and a breached divide on the uplands, the three being intimately associated. Taylor has also referred to Kangaroo River—a more easterly tributary of the lower Shoalhaven—as having flowed originally westward past Tallong to the postulated main stream. Andrews, the pioneer of Australian physiography, regarded the lower Shoalhaven as an eastward-flowing stream of considerable antiquity—a conclusion which would appear to be amply supported by the field evidence adduced here.

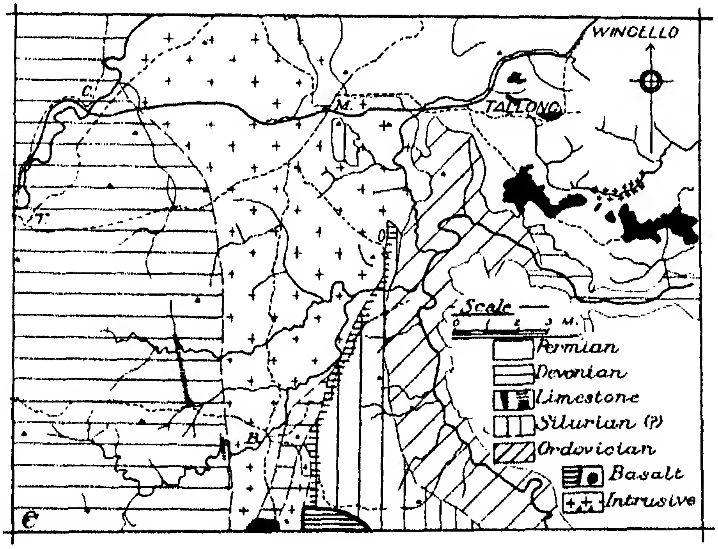
The paper by Woolnough on the Geology of Tallong has been largely availed of, and Dr. Woolnough's map is incorporated in Text-fig. 2. On the geological side reference may be made to recent accounts of Tertiary contact quartzites by Ida Brown (1926) and Waterhouse and Browne (1929).

As regards physiography, detailed work has not been done over any part of the Shoalhaven Valley and, although Woolnough and Taylor's capture hypothesis has been criticized, no alternative explanation has been published.

Geology and Resistance to Erosion. (Text-fig. 2.)

The physiography of the district has been greatly affected by the character and structure of the rocks. Systems ranging in age from Tertiary to Ordovician are represented, in addition to intrusive and volcanic igneous rocks. These may be classified for present purposes as follows:

Tertiary.—Quartzites are found near flows of Tertiary basalt and in places from which basalt has presumably been eroded. This material has been referred to as silicified Tertiary sands by Brown (1925), and has been described by



Text-fig. 2.—Geological Sketch Map of the Area. Other details are shown on Plates v and vi, and Text-fig. 8. Triassic strata occur in the extreme north-east.

Waterhouse and Browne (1929). The quartzite is generally white or light-grey in colour, is brittle, and generally breaks with a conchoidal fracture. It contains crystals of quartz up to a half-inch across, and is easily distinguished from the fine-grained and much more resistant older quartzites. It resists weathering much more than the overlying basalt, and is frequently found quite away from any surviving flows (Text-fig. 8). Notable occurrences of this latter type are to the west of Ballanya Trig. Station (2,000 feet); to the south of Jerrara Creek (1,950 feet); on a hill near Bungonia Trig. Station (2,000 feet); and to the south of Bungonia Creek (1,870 to 1,970 feet). It will be seen that these occurrences correspond over a limited range, and compare with the base of the Caoura flow

(between Tallowa Creek and the Shoalhaven River), which is below 1,850 feet on its eastern extremity.

This quartzitic material is readily distinguished from older sandstones which have been invaded by intrusive rocks. Examples of these latter are found at Bungonia Trig. Station and on the Goulburn road, a mile and a half west of Bungonia at 2,020 feet. In these cases the sandstone is altered to quartzite in places and has been strongly jointed by pressure, thus breaking into irregular fragments. It contrasts with the porcelain-like Tertiary contact quartzite.

The recognition of this Tertiary material is physiographically important, as it indicates surfaces which existed immediately before the period of basalt flows.

Permian.—Triassic strata hardly occur in this area, although they are extensively developed to the north-east, the edge of the series probably being near Wingello. The Permian Upper Coal Measures and Upper Marine Series are extensively developed, but it is not easy to distinguish between the two, nor is it necessary from a physiographic point of view. At the base of the system near its western edge there are massive beds of conglomerate up to 400 feet thick (Woolnough), which dip gently northward and eastward, and give place to finer sediments. They form a resistant bank on the northern side of Barber's Creek at Tallong, where they consist largely of subangular and rounded quartz pebbles up to 8 inches in diameter. They are shore-line deposits flanking older masses such as Ballanya Hill. A horizon of conglomerate, sandstone and grit in contact with old Palaeozoic rocks marks the base of the Upper Marine Series, and forms a level tableland on either side of the lower Shoalhaven (*i.e.*, below Barber's Creek).

Above this horizon are shales, shaly sandstones and soft sandstones, some of them fine-grained sediments containing masses of quartzite and quartz-porphyry up to 2 feet in diameter, as at the head of Tallowa Creek. In this particular locality the softer rocks have surface impregnations of iron oxide and a limited covering of bauxite, both having been derived from Tertiary basalts and both helping to preserve a level surface to the tableland to the north of Tallowa Creek (Text-fig. 6).

The pebbles of the conglomerates are mainly siliceous metamorphic types with a considerable amount of white reef-quartz. To the north of Barber's Creek the conglomerate bank gives place to shales and sandstones with occasional pebble beds, the change being accompanied by more mature land forms at the head of Uringalla Creek. The master joints of these rocks are approximately north-south and east-west in direction, thus determining the major cliff lines above the modern gorges.

Older Palaeozoic.—Woolnough has described Silurian and Ordovician rocks in the neighbourhood of Marulan. The latter comprise highly-folded shales, slates, cherts and quartzites striking about N. 10° W., whilst the former include slates and limestones whose strike varies from north to N. 35° E. Their dip is about 45° west, and they are overlain on the western side by Devonian slates, shales and quartzites with a similar dip. This conformity has been noticed further south at Windellama, and it is possible that both series are of Devonian age. These rocks have been intruded by granites, and their strike curves in sympathy with the boundaries of the intrusion.

From the physiographic point of view the Devonian series is the most interesting, as the older strata have been reduced to form plains of low relief in the uplands, whilst the Devonian country is marked by the presence of high

ridges. The older rocks are broken into small sections by intense jointing and this, added to their natural thin bedding, makes even the hardest of them quite susceptible to mechanical erosion. The Devonian strata, on the other hand, contain beds of massive quartzites separated by weaker slates, shales and limestones. Their edges have been exposed by folding and, as the result of prolonged erosion, the softer rocks have been removed to form a series of strike valleys (Text-fig. 7), whilst the quartzites stand up as parallel isoclinal ridges rising to 800 feet above the valleys.

Igneous.—Reference has already been made to the basalts of the uplands. The Tertiary age ascribed to these depends on the evidence of plant remains found at their base at Wingello, Penrose and the Moss Vale district, and on this ground they are generally referred to as of Pliocene age. Physiographically they can be classed together, as they are found in valleys cut to a common depth of 300 feet in a peneplain surface. They antedate the main uplifts which have produced the present tableland, as those have caused new cycles of erosion to come into existence and to be impressed on the old plain surfaces, of which the basalts form an integral part.

A belt of acid intrusives extends from Tallong southward past Bungonia. It has been described by Woolnough as having a somewhat sill-like form with westerly underlie, although it is not a sill. He points out that, for the Marulan-Tallong area, the mass comprises granodiorite, which passes into dacite and quartz-porphyry towards the west. Acid types continue southward towards Bungonia, with fine-grained felsites on the eastern edge and quartz-porphyry to the west. The general effect of the intrusion has been to give a series of rocks which form undulating surfaces when exposed to weathering over long periods.

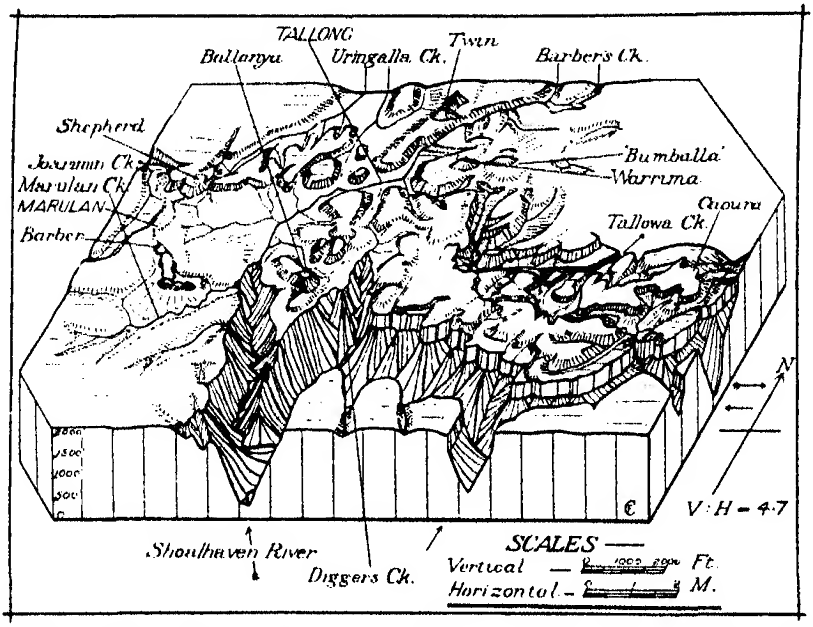
From the behaviour of these various rocks when placed in juxtaposition and subjected to uniform attack by weathering and erosion, a fairly accurate idea of their total resistance to these forces may be gained. The outstandingly resistant members are the Devonian quartzites, whilst their associated shales and slates are strongly jointed, fissile and offer comparatively small resistance. Using this topographic basis, of which many illustrations will be found in the succeeding pages, we obtain this scheme, using a descending order of total resistance: (i) Massive Devonian quartzites; (ii) Ordovician quartzites and cherts: various cherts and jaspers; (iii) Tertiary quartzites: porphyries; (iv) Permian conglomerates: Tertiary basalt: acid granite; (v) Granodiorite: Permian sandstones; (vi) Older Palaeozoic slates, shales and limestones: Permian shales.

Topography and Physiography.

1. *Tallong* (Plates v, vi; Text-figs. 3, 6, 9).—Referring to the topographic map it is seen that the vicinity of Tallong is a low maturely-dissected tableland. The double residual which forms Twin Trig. Station at 2,350 feet is capped with hard sandstone, and rises a clear 150 feet above the surrounding country at 2,200 feet. This, in its turn, is 200 feet higher than the plains extending from Tallong toward Marulan.

The area between Barber's Creek and the main road is drained by Uringalla Creek, which flows in a series of broad, mature valleys up to 200 feet deep. The three heads of this stream form a beautiful drainage pattern, although this fact is obscured in the field by dense scrub growing in the flat, alluviated bottoms. The hillsides are covered with sandy soil and pebble drift from the conglomerates which, in this part, are much weakened by the presence of soft shales and sand-

stones, thus contrasting with the hard bank immediately to the north of Barber's Creek. Of the three heads of Uringalla Creek "A", whose valley is used by the main road, has a gentle grade into alluviated swampy plains up to a half-mile in width. "B" flows through a flat valley and, after heavy rain, it spreads a thin



Text-fig. 3.—Block Diagram of the Tallong District. Note the upper tableland surface, the wide upland valleys and the Caoura basalt flow.

covering of very fine mud over a width of 200 yards; passing the 2,000 feet contour its channel is more definite, although lost in beds of sword grass at intervals. The third head is known locally as "Chain of Ponds", on account of four small ponds occurring in a bend off a quartzite inlier. The ponds are situated in thick, rich black soil at a place where much fine wash has been carried in from tributary valleys. Below this point the stream runs through narrow swamps on to a wide, marshy flat a little below 2,000 feet. Its course here is quite indefinite, but above the ponds a narrowing mature valley is found, through which the stream flows gently.

The local base-level is slightly below 2,000 feet, and erosion has progressed to a point of equilibrium where the force of falling rain-water on the hillsides is insufficient to carry any but the finest material into the streams.

Areas of flat ground with indefinite drainage are found in the continuous valley at the head of Marsh's Creek. This small stream, with a slight advantage in grade over Uringalla "B", is cutting slowly into the swamps. The divide between the Shoalhaven and Wollondilly waters has a minimum elevation here of 2,025 feet, and the conditions are those of mature dissection. The higher plain at 2,200 feet has been dissected to 2,000 feet, whilst the higher Twin residual points to the former existence of a still older and higher land surface.

ii. *Barber's Creek–Eastern Valleys* (Plates v, vi; Text-figs. 3, 6).—The basalt hills of Warrima and Bumballa slope gently northward and give place to wide valleys between 2,100 and 2,200 feet. These slopes act as the gathering grounds of Barber's Creek, which is also greatly assisted by level swamps on sandstone country to the north-east. The hills around the eastern and southern edges of the basalt rise to 2,250 feet, and are marked by deposits of pisolitic bauxite containing a good deal of iron, the whole having been derived from the basalts and associated tuffs. This material extends southward over flat land to the edges of the gullies of George's and Tallowa Creeks, these gullies being essentially post-basaltic features. A similar remark is equally applicable to the level, swampy valleys in which Barber's Creek heads.

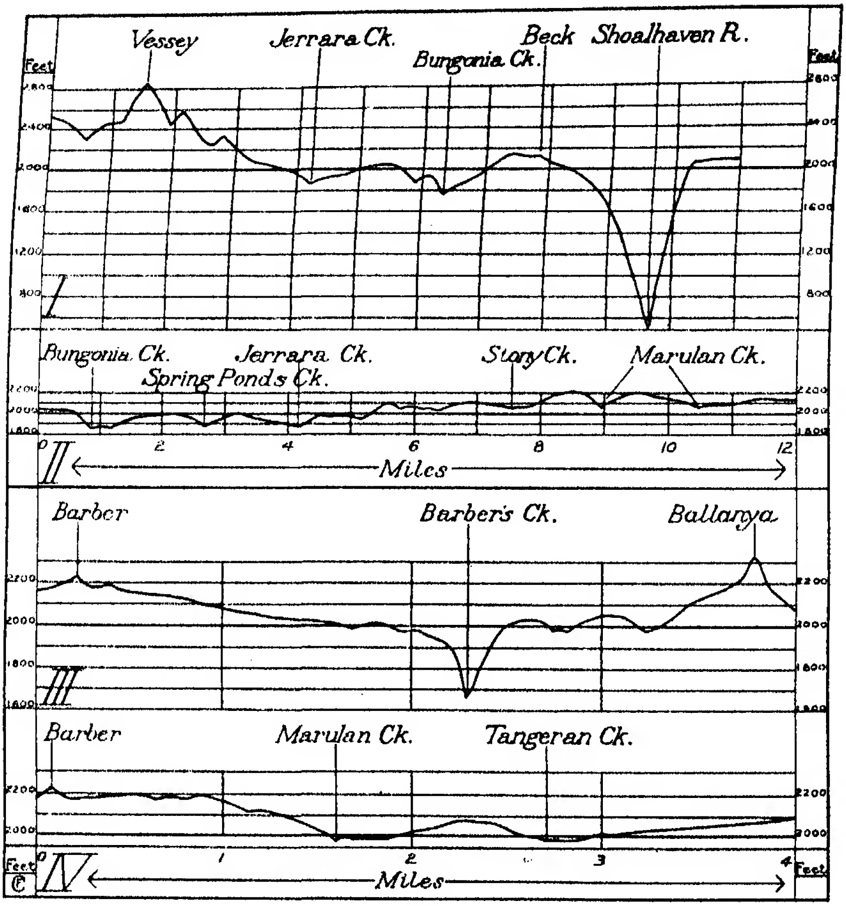
It would appear that swamps existed on the pre-basaltic surface about the (modern) elevation of 2,200 feet and, after the extrusion of basalt and the formation of the bauxite horizon at this level, Barber's Creek has gradually reduced its headwater country in elevation and retains its original swampy nature in parts, whilst originally similar country to the south-east has been drained and dissected by steeper streams flowing to Tallowa Creek.

Looking down the valley of Barber's Creek from Warrima Trig. Station, a gentle and rather indefinite slope westward beyond Tallong is noticed, leading to the granite plains toward Marulan. Certain youthful features are developed on the floor of this valley, the main head streams having steep banks and cliffs on their northern sides. Their southern slopes are, however, much gentler, and the valleys have a slightly asymmetric character. The lowest point noticed on the western side of the Warrima basalt is on the base of the more northern isolated mass at 2,150 feet. Thus the original pre-basaltic slope from this part of the tableland to the granite plains at 2,000 feet must have been quite gentle.

Taken as a whole, the upper valleys of Barber's Creek show the higher levels being attacked by streams based on 2,000 feet, although the degree of maturity of dissection reached is not so great as in the case of the head streams of Uringalla Creek. Still, the divide between this part of the system and Digger's Creek is quite low, being just below 2,100 feet.

iii. *Barber's Creek–Western Valleys* (Plate vi; Text-figs. 3, 4, 5, 8).—Passing down Barber's Creek from Tallong the topography changes abruptly. That part of the stream which flows southward drains a valley two miles wide, lying between dissected strike ridges of ancient rocks (Text-fig. 4). Proceeding southward, this valley widens out to form a considerable plain extending for many miles on the western side of the Shoalhaven gorge.

There are three tributary streams from the west—Tangeran and Marulan Creeks, and the indefinite stream which drains the flats lying east of Marulan. The latter heads between Barber and Shepherd Trig. Stations, and its upper courses are cutting back slowly into the low watershed, giving a gently-rounded topography. Proceeding down the valley towards Barber's Creek a level plain at 2,000 feet is crossed, which is bounded on the north by a long, straight conglomerate ridge. The plain is covered with sandy and gravelly wash and the stream courses are, for the most part, quite indefinite. Going southward across the railway one passes on to a gently undulating slope, which falls from the metamorphic ridge on the west into Barber's Creek. Granite tors and low knolls are features of the landscape which, in turn, give place to the broad valleys of Marulan and Tangeran Creeks.



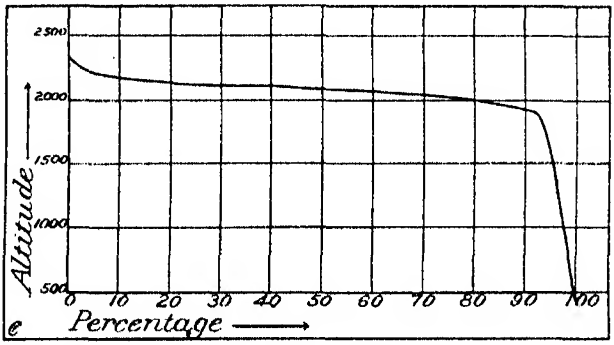
Text-fig. 4.—Profiles: i. Showing the residuals, the Shoalhaven Plain and gorge; ii. Marulan to Bungonia, showing the upper slopes, the 2,000 foot plain and modern valleys in the plain surface; iii. Valley of Barber's Creek; iv. The Barber ridge and tributaries of Barber's Creek. Vertical exaggeration of i and ii = 8·8; of iii and iv = 5·9.

The ridge on which Barber Trig. Station is situated forms a contrast to the surrounding country. Owing to its steeper and more rocky nature, combined with the poorness of its soil, it has been left uncleared, and stands out sharply above the surrounding clear plain. Head streams of Marulan Creek rise in gentle valleys on three sides of this ridge, those going to the east and south falling gently to the main stream, whilst those on the western side lead to considerable areas of barren flats.

In these level valleys the soil covering on the lower slopes is up to 15 feet thick, the surface portion being light and sandy whilst the bottom portions are clayey, and contain a basal layer of pebbles up to 3 feet thick. Soil from the

weathering hillsides has drifted over the pebble wash of the original stream beds. Above the 2,000 foot contour the pebble layer is not prominent, and the wash is only about 5 feet thick, whilst below 1,900 feet the streams run into gorges leading to Barber's Creek. Following the destruction of the original trees, the ravages of rabbits and the stocking of the country, these areas of drift along the stream courses are being eroded rapidly, and the good land is being invaded by a network of gullies.

One of the most striking features of Marulan Creek is its great erosive power in time of flood. The channel is from 10 to 30 yards wide and, for the greater part of its length, it is strewn with rock fragments. Cubes and more irregular pieces of fresh granite with edges up to 2 feet have been torn from the stream bed, and are carried freely by flood waters. The ruling grade of this stream is 1 in 90. Tangeran Creek is similar to this stream, and both are notable for the precipitous gorges through which they fall to the main stream.



Text-fig. 5.—Average Profile for the basin of Barber's Creek. Altitude is shown in feet above sea-level. The total area concerned is 33·4 square miles, and the graph demonstrates the first stage in the dissection of a mature tableland surface, the steep lower slope representing the canyons which have been cut as the result of recent uplift.

Falling to Barber's Creek from the east there are small streams which are similar to those on the western side, the most notable being Dog Trap Creek. This rises on clay flats to the east of Ballanya Trig. Station, and passes across the ridge line in a narrow, mature valley. Its course over weathered granodiorite is true to type, but its sediments are better differentiated than those of Marulan Creek. A typical section 800 yards above Barber's Creek reveals 8 feet of sandy drift resting on 1 foot of small quartzite pebbles and angular fragments which, in turn, overlie white clay. The small streams further south are similar, but lack the quartzite pebbles in their drift.

Turning to Barber's Creek itself, we find the greater part of this section entrenched in a deep gorge whose sides are perpendicular in places. The head of erosion is marked by waterfalls aggregating 300 feet in height but, above the head of the falls, a narrow trench 100 feet deep extends back for some 300 yards into the undulating valley. This would appear to be due to local vertical downcutting resulting from the increased horizontal velocity of the water as it approaches the steeper grade downstream, although the grade in the section so

affected only changes very gradually. This feature is found above most of the waterfalls on the edge of our plateau scarp.

Having obtained some idea of the appearance of this section, we may now survey its physiography. The higher tableland levels at 2,200 feet which are found to the east only exist here as isolated ridges. The predominant level is that based on 2,000 feet (Text-fig. 5), including those plains by the railway at a slightly lower elevation. The country at the heads of the western tributaries rises gently to 2,100 feet, but is part of the same gentle slopes. The plain has been cut into by a series of gentle valleys whose floors are covered with deep well-differentiated drift, itself indicative of mature and stable conditions. Remains of silicified sands and conglomerates occur on the eastern side at 2,000 feet, and would appear to have been associated with the basalt flows, thus giving an indication of the age of part, at least, of this valley.

The present maturity of the landscape when compared with the country further east is closely associated with its geology for, as Browne (1928) again emphasizes, granites may weather to a considerable depth before actually being subjected to the active forces of erosion. Such a process has not affected the surrounding sedimentary rocks so, when the plain at 2,200 or 2,300 feet was first subjected to erosion, great quantities of the weathered granite would be readily eroded, leaving the chemically inactive rocks as residuals.

But, despite this variation in the amount of denudation, the streams operating on different rocks have cut down to a common level, from 200 to 300 feet below the surface of the original plain, and the great widening of the lower valley of Barber's Creek and the valleys of its tributaries has been accomplished since this level was reached. This process is still continuing, and even the porphyries to the west of Marulan are being attacked readily because, in many places, their groundmass has been decomposed to a soft clay to some depth below the surface.

This part of the area is of particular interest in that the older plain, now at 2,200 feet, is well preserved in the horizontal sedimentary rocks, whilst its distinctive character in the rocks liable to extensive pre-erosional rotting has been largely destroyed. The wide valleys may be classed as "mature"—or even, perhaps, as part of an incomplete peneplain—but the narrower valleys about the head of Uringalla Creek are quite as ancient, and the streams have cut their divides down almost to the 2,000 foot level, which is the common local base.

iv. *Digger's Creek*.—The greater part of the course of this small stream is in a deep gorge. The principal drainage area is crossed by the Tallong to Caoura road, where the deep soils covering the slopes between 2,000 and 2,200 feet store up a good deal of water and give a small permanent flow. On the western side, Dog Trap Creek takes part of the drainage which one would expect to go into Digger's Creek, especially as the gorge of the latter has almost reached the indefinite, soft divide which separates the two runs.

At the point where the stream begins to fall there are beds of level alluvial material containing somewhat rounded fragments of quartzite from the hillsides to the south-east. This material has a thickness of 5 to 10 feet, and its surface at 1,990 feet comes right to the edge of a trench, 100 feet deep, which marks the commencement of the gorge. Above this fall in the modern stream-bed there are small aggradation flats in the concave stream bends between 1,960 and 1,990 feet, from which a little gold has been won.

On the western or Ballanya side the local 1,990 foot level is continued as a pebble horizon (Plate vi, inset). The pebbles are up to 2 feet in diameter and consist mainly of brown sandstone and quartzite of ellipsoidal shape which have been derived from solid conglomerate resting on an agglomerate base at 1,950 feet. Underlying rocks are slates and quartzites, and angular masses of these pass upward into the horizontal strata and some of the pieces, weathered from the surrounding material, are found in the small stream channels. Above the conglomerate there is a fine-grained ferruginous sandstone and grit containing small pieces of white reef-quartz above which, and up to 2,050 feet, the slopes are covered with sandy soil containing quartz and quartzite pebbles up to 5 inches in diameter.

This deposit probably represents an outlier of the Upper Marine Series, other relics of a slightly different character occurring about the older rocks (Text-fig. 8). Standing on the loose surface pebbles above the gorge of Digger's Creek and looking northward, the pebble and conglomerate bed is seen to be enclosed on all except the gorge side by a low bank. Part of this is a spur from Ballanya Trig. Station, and forms the divide between Digger's and Dog Trap Creeks. Excavations for a water supply tunnel across this ridge at 2,050 feet have disclosed the presence of the older folded slates, which are weathering to a white clay, and which are strewn over by quartz drift as one approaches the head of the gorge.

Passing from this ridge down the valley of Dog Trap Creek one finds the lowest part of the divide at 2,030 feet, and the westward fall is over flats of fine clay. A uniformly gentle fall leads to the edge of the granite country at 2,000 feet, where the stream flows over a bar of white quartzite to emerge on the plain.

The gorge of Digger's Creek is steep-sided and rough, and the activity of the stream has resulted in the deposition of a bank of detritus at its junction with the Shoalhaven River. The considerable size of this gorge when compared with that of Barber's Creek—a much more powerful stream—is readily accounted for by the fact that it is cut parallel to the strike of the Ordovician slate in which it exists, whilst the gorge of the latter stream is cut in massive and comparatively fresh granodiorite.

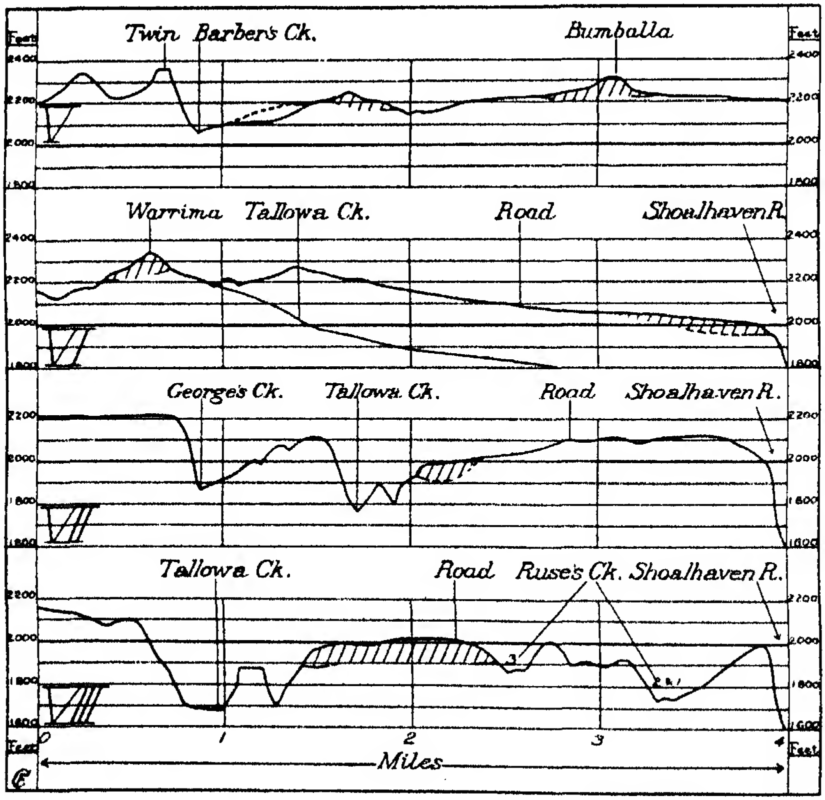
The main points of note in this section are the conglomerate relics, which had been described by Woolnough and Taylor (1906) as fairly recent stream gravel, and the flats at the head of the stream formed as the result of erosion in the edge of the Permian series. In fact, the periphery of these strata is marked by a continuous valley extending northward to the Wollondilly basin.

v. *The Area of Basalt Flows* (Plates v, vi; Text-figs. 3, 6 and 10).—The basalts of Warrima and Bumballa probably represent original centres of extrusion, and there may be others in the neighbourhood of Badgery's Lookout (*fide* Woolnough, 1909, and Geology Dept. of the University). There is a possibility that some basalt came from the direction of Warrima and contributed towards the flow which extends from Badgery's Lookout to Caoura Trig. Station (Plate v), but, so far as physiography is concerned, the origin of the Caoura flow is not a matter of great importance.

The head of Tallowa Creek occupies a broad valley cut in the eastern flank of the Warrima basalt but, near Bumballa, the stream runs into a rough gully

200 feet deep which is surmounted by sandstone cliffs up to 60 feet high (not shown on the contour map). Small tributary runs have formed bays on either side of the main gully, and these conditions continue until George's Creek is reached. On the northern side of its valley is a steep bank, but the southern slopes are quite gentle (Text-fig. 6). This valley is incised 300 feet below the bauxite level, and its width is due to its being eroded in soft sandstones and shales.

Below this stream Tallowa Creek flows into a characteristic gully. On its northern side is a flat hill at 2,100 feet which slopes uniformly into the creek. To the south are sandstone terraces at 1,800 to 1,950 feet, which are surmounted by basalt. Passing a mile downstream the basalt comes almost to the creek in a place where both sides of the gully are quite gentle. Here there is also an extensive terrace on the northern side, which ends abruptly against a steep bank 150 feet high. The second hill on this side forms a distinct peninsula and, on either side of the gully, terraces are well developed between 1,850 and 1,900 feet. Here the gully is becoming a gorge, and the horizontal sandstones are under-



Text-fig. 6.—Profiles across the eastern basalt flows. Note the 2,200 foot plain, the Twin residual, the basalt-filled valley and the valleys due to post-basaltic erosion. Basalts are hatched. Vertical exaggeration = 5·9.

lain by hard porphyries through which the stream is cutting. Essentially similar conditions continue eastward to the junction of Tallowa with Bundanoon Creek and the Kangaroo River. Four miles east of Caoura Trig. Station the terrace has fallen to 1,500 feet, and the gentle fall continues eastward.

Let us now consider the actual basalt flow. The western end is a level plain and, where small streams falling to the Shoalhaven have trenched it, they reveal the base to lie at, or possibly below, 1,950 feet, giving an existing maximum thickness of at least 130 feet. As the result of erosion, there have been developed at this end steep banks which stand above the cliff edges of the Shoalhaven gorge, though a little back from it. Off the edge of the flow there has been considerable contact metamorphism giving a glassy quartzite up to 6 feet in thickness, as in the creek bed to the east of the Lookout. These contacts are valuable as defining the limits of the valley which the basalt has filled and are, in general, close to the former edge of the flow. Remnants of lateral valleys are preserved in places. This part of the flow is of square shape with sides a mile in length.

Continuing eastward parallel to Tallowa Gully the width of the flow diminishes, although the generally plain character of its surface persists between converging hills. At the first constriction the basalt is only 400 yards wide, although contacts point to a former width of 700 yards. Here a ridge of soft sandstone and shale rises southward to a height of 140 feet above the basalt surface. Still proceeding east we find that three transverse streams have cut right across the flow, giving two isolated masses with an appearance not unlike that of huge pancakes. The line of maximum thickness here trends south-east and north-west and, although the absolute thickness of the basalt is obscured by drift from the steep crowning banks, it is not less than 150 feet, and the lowest part of the base is, at most, 1,850 feet above sea-level.

Passing these isolated areas, the line is found to continue for two miles to Caoura Trig. Station and the flow preserves a fair width, although it is almost cut across in places. The northern edge is defined with some certainty by contacts from 1,900 feet upwards, and erosion has apparently removed a maximum width at the constriction. The southern edge is by no means as certain because, as the quartzite hill near Ruse's Creek (1,700 yards SW. of Caoura Trig.) shows, erosion has played a considerable part. The maximum thickness of the basalt seems to be 200 feet near Caoura Trig., where an almost precipitous bank overlooks the head of Bullangalong Creek. The outlier to the south-east of the trigonometrical station and immediately above the Shoalhaven cliffs is probably a branch of the main flow, which points towards the place where Bullangalong Creek crosses the cliffs of the Shoalhaven gorge. Isolated relics further east ("White's Selection") also point towards this locality.

The basalt is thus found to occupy a definite valley, both commencing and ending above the main gorge (Plate v). The original valley is well preserved, and exists to the present day as a definite topographic feature through the greater part of its original length. Between this valley and the Shoalhaven cliffs is an area of plain country between 2,000 and 2,100 feet, which has been maturely dissected by the head streams of Ruse's Creek (marked 1, 2, 3 and 4 on the map), and to a much less extent by other smaller streams.

Of the heads of Ruse's Creek, 4 and the upper parts of 2 are lateral streams; 3 may have been a transverse stream, whilst 1 is not connected with the basalt.

The four valleys unite to form a broad, irregular amphitheatre, and they are mature to 1,750 feet (Text-fig. 10); 1, 2 and parts of 4 are well graded with alluviated courses and stretches of swamp, and they flow in U-shaped valleys. On the south of 1 is a line of hills overlooking the river, and cut off sharply by great precipices; 1 and the Shoalhaven River are horizontally equidistant from this line of hills.

The western head of Bullangalong Creek flows in a rather similar valley to the preceding, but its sides are higher and steeper. This section was probably a transverse stream. To the west of Ruse's Creek the land is crossed by gentle stream beds which only become entrenched near the edge of the cliffs.

We may now consider the development of the topography, beginning with the more recent forms.

The valleys to the south of the basalt flow are necessarily post-basaltic. This also applies to the transverse valleys falling to Tallowa Creek and to the sandstone benches along that stream. It may also be stated that the valley now occupied by basalt originally fell into the Shoalhaven about the vicinity of the modern Bullangalong Creek, and that the upper part of Tallowa Creek—at least that part within the basalt flow section—is more recent than the basalts. This latter is, in fact, separated from the wider and lower parts of the terraces by a neck of high land to the east of Caoura.

In the case of the mature and sub-mature valleys above the river, we have a clear differentiation between them and the great gorge to which their streams fall, and their lower parts are now being attacked with considerable force, causing the recession of cliffs and waterfalls and the development of more youthful features.

The basalt flow itself is seen to occupy a linear valley whose original character can be inferred from the maps and sections (see Text-fig. 6). In form it was approaching maturity, and would appear to have resembled the upland valley of Digger's Creek in having broad and level sections connected by a narrower channel. The steep bank on the northern side of Tallowa Creek would appear to be the old valley side considerably steepened by erosion. Its recession has not been uniform, but the presence of outstanding "capes" is probably due to locally hard patches in the surface covering of sandstone. To get the pre-basaltic profiles we may take a gentle slope from the 2,200 foot plain on the northern side to the present northern edge of the basalt, so that it coincides with the inward-dipping contact quartzite. The southern side is still fairly well preserved in its central section, and the destruction of the original northern profile measures the post-basaltic erosion.

We have thus come back to pre-basaltic conditions, where the 2,200 foot plain was trenched by a simple valley to a depth of 350 feet, whose sides were being attacked by tributary streams. That this process had not gone very far is shown by the ground plan of the basalt-filled valley, which has no important branches. On the higher plain to the north erosion has also progressed in two stages. The head of Tallowa Creek is in a mature post-basaltic valley which is now being attacked by the streams with the resultant formation of a steep gully (Text-fig. 6). The 2,000 foot level is represented in the neighbourhood of Badgery's Lookout, but not so definitely as in the case of Barber's Creek. The basalt-filled

valley with increasing depth eastward seems to represent a distinct phase in erosion below 2,000 feet, this stage having been continued towards maturity by Ruse's and Bullangalong Creeks.

Using 2,200 feet as zero, a comparison between the physiographic forms dealt with up to the present may be made:

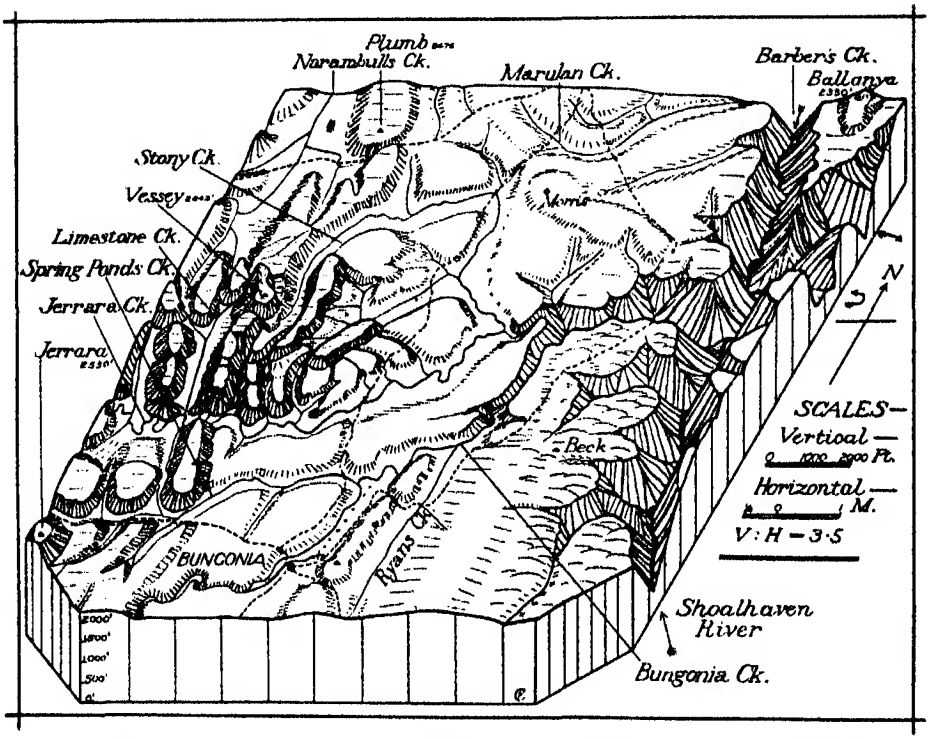
Feature.	Cycle or Part Cycle.	Vertical Height.	Comparative Age.
Residuals	1	+ 150′	Pre-basaltic
Tableland	2	0	Pre-basaltic
Valley of Barber's Creek	3	− 200′	Pre-basaltic (Since extended)
Digger's Creek	3	− 160′	Pre-basaltic
Valley between Lookout and Caoura ..	4	− 350′	Pre-basaltic
Terraces of Tallowa	4	− 400′	Post-basaltic
Ruse's and Bullangalong Creeks	4	− 500′	Post-basaltic
Upper levels of Tallowa Creek, 4 miles E. of Caoura	4	− 700′	Post-basaltic
Canyon of Shoalhaven River	5	− 1900′	Post-basaltic

Of these cycles or part cycles of erosion, only traces of the first remain; the second was completed, and its effects have been largely obscured by the third. The fourth and fifth are notably incomplete, the effect of the former in particular virtually being confined to the country east of Barber's Creek, and being more pronounced as one goes further eastward. The conclusion is that erosive forces have operated towards the east and have either not been applicable to the west on account of essentially different conditions of elevation, or did not have time to push further westward before the cutting of the canyons as they exist at present. The remarkable topographic uniformity of the tableland surface between the Wollondilly River and the Illawarra coastal highlands, when taken in conjunction with the forms already described in this paper, certainly suggests uniform normal uplift, and the balance of evidence is in favour of the latter alternative of extra part-cycles towards the coast.

There is also a definite suggestion that the last stages in the elevation of the plateau involved an essentially constant uplift of the order of 1,000 feet, thus allowing for the difference between the base-level of the modern gorges (i.e. sea-level), and a former base-level now represented by the lowest limits of part-cycle 4. In other words, base-level has remained constant within narrow limits, but the old surfaces have been uplifted.

In all this it must be remembered that Caoura is only 25 miles from Nowra, and although that town is 15 miles from the sea, the nature and extent of the deltaic deposits below it suggest that the Shoalhaven River at Nowra has been at sea-level over a very long period of time, and the forces of erosion have had ideal conditions for their attack on the immediate hinterland, from which the softer surface material has been removed during pauses in the uplift, giving a distinctive series of part-cycles of erosion which disappear as one goes westward.

vi. *The Bungonia Creek System* (Text-figs. 4, 7, 8, 10).—On the western side of the Shoalhaven gorge there is an extensive plain up to 8 miles in width which is dominated by high residual ridges. The river itself is deeply entrenched in this plain, and some of its tributaries have cut sharply into the sides of the main gorge. The westward ridges are broken and rocky but, as most of them have been breached by streams, they are by no means inaccessible. It is convenient to discuss these separately from the plain.



Text-fig. 7.—Block Diagram of the Bungonia Creek System. Note the residuals in westward-dipping rocks on the west, the Shoalhaven Plain in the centre, and the modern gorges on the east.

a. The Residual Ridges.—These owe their existence to the hard and resistant nature of the quartzite of which they are composed. The strata dip west at an average angle of 45 degrees, so the phenomenon of alternating dip slopes and scarps gives equal eastward and westward slopes. Interbedded with these harder rocks are less resistant shales and slates and a bed of limestone, which have been generally—although not uniformly—weathered away to form a series of deep valleys. The topography thus suggests a series of rather sharp waves whose axes are parallel to the strike and are, therefore, meridional.

The master ridge lies to the east of Gundary Creek and includes the heights of Gundary and Towrang Trig. Stations. In structure it is synclinal, with the

steeper limb on the eastern side. It forms the western watershed of Jerrara and Bungonia Creeks and separates those streams from the Wollondilly waters although, near Towrang, it is entirely within the Wollondilly system. On the eastern side of this master ridge, which rises to 2,845 feet, there are three lower ridges varying from 2,400 to 2,530 feet. They are cut across by the main streams, whose tributaries have eroded deep strike valleys between them. Divides between these latter are quite low and easily travelled. Passing eastward we reach another high ridge, highest at Vessey Trig. where it reaches 2,842 feet, and falling both to the north and south. Here the prevailing quartzite is relieved by the presence of fossiliferous breccia.

The Vessey ridge is buttressed on its eastern side by two shorter and lower ridges at 2,600 and 2,300 feet respectively whose central points are joined by lower cross ridges forming the starting points of short meridional valleys. Those on the north fall to Stony Creek, whilst the more southerly enter the valley of Jerrara Creek. These ridges mark the eastern boundary of the quartzite strata, and where the zone of intrusive quartz-porphyries is reached, the country falls in a series of poorly-defined terraces at 2,200 and 2,100 feet to the Shoalhaven Plain.

Of the streams which flow through the residual country Jerrara Creek is the most notable. Rising on the eastern side of the master ridge in a flat-bottomed valley at 2,250 feet, it flows eastward past the three lower ridges, and crosses the western limestone belt at 1,960 feet, having come through a mature valley. Looking upstream from the limestone belt at Pearce's homestead, a distinct terrace at 2,100 feet is observed, about 100 feet above the modern stream flats. This higher level extends to 400 yards on either side of the stream, and forms a notable minor feature.

A small stream comes along the limestone from the west of Vessey Trig., and flows through a flat-bottomed valley a mile and a half long. Only the lower 700 yards are actually in limestone, which disappears northward and is replaced by shales. Where it does occur, its eastern edge is marked by bluffs of impure haematite and limonite rising to 30 feet above their bases. These are the result of concentration of oxides of iron from the limestone and neighbouring slates at the base of the westward-dipping limestone, part of which has since been removed by solution. This valley lies between 2,000 and 2,150 feet, and it is separated from Narambull's Creek by a col at 2,300 feet which joins Vessey with the westward ridge at 2,530 feet.

Narambull's Creek falls gently through a widening valley to Shelley Flat on the Southern Highway, and past there to the Wollondilly.

The western limestone belt can be traced to Spring Ponds Creek, about 2 miles south of Jerrara Creek, between which two streams it and the associated slates are responsible for a lower place in the divide at 2,160 feet. Below this limestone Jerrara Creek passes on to slates and quartzites. The hills close in and the stream flats and terraces disappear for some hundreds of yards (Plate iv, fig. 2) as the stream crosses the hard strata of the Vessey mass, which stands up grim and solid on the northern side. After passing this harder bar at a gentle grade, the stream flows into a wider valley with flats up to 400 yards wide on the left bank at an elevation of 1,950 feet. These continue downstream for a half-mile, the country on either side becoming progressively lower. Then once again the valley narrows, and the flats almost disappear as the stream cuts through the hard

western edge of the porphyries. These conditions continue for half a mile, after which the stream emerges on to extensive levels at 1,920 feet. Here it follows a gentle course through sandy drift about 4 feet deep overlying beds of water-worn pebbles, consisting of quartzite and quartz-porphyry. The material is roughly stratified, and is being eroded rapidly following the removal of trees from the banks. From this point there is a gentle fall past the Bungonia road, this part of the stream being in a late mature valley on the Shoalhaven Plain. It will be seen that the topography of this creek is that of an ancient stream which has been flowing across rocks of vastly differing degrees of hardness over a long period of time.

On the northern side of the Vessey mass are the valleys of Stony Creek at 2,200 feet which, like those of Jerrara Creek, have been determined in their upper courses by the prevailing rock strike. The main stream turns south-eastward to fall across the Bungonia road at 2,030 feet to its junction with Jerrara Creek at 1,800 feet. The Vessey ridge forms its western divide, and the ridges between the tributaries rise from 2,250 feet on the east to 2,500 feet on the west.

The heads of Spring Ponds and Bungonia Creeks are also in the ridge country. The former rises in level valleys between 2,000 and 2,050 feet, the two main heads being separated by a ridge 200 feet higher. Its main course is across the plain. Many of the head streams of Bungonia Creek also rise in level valleys in the ridge country at 2,100 feet, but they flow past the ridges where the latter are much lower and less impressive than in the case of Jerrara Creek. By far the greater part of the course of this stream lies on the plain, across which it flows in a shallow trench up to 100 feet deep.

b. The Shoalhaven Plain.—Looking eastward from the heights about Vessey Trig., an extensive plain is seen to extend on either side of the Shoalhaven River, that part on the western side of the gorge being a little lower than the eastern section. This plain includes the lower parts of the basins of Barber's, Bungonia and Nerrimunga Creeks, and is marked by low relief and very subdued divides. It forms a striking contrast to the ridge country and, upon examination, it discloses a long and varied history.

The dividing ridge between Barber's and Stony Creeks rises to 2,265 feet at Morris Trig. Station, although the greater part is about 2,200 feet. The slopes of this ridge are gentle, and quite characteristic of granite country. The valley of Stony Creek falls uniformly to the south of this ridge and the course of the stream at 1,850 feet half a mile above its junction with Jerrara Creek discloses an entrenchment of the order of 100 feet in the level surrounding plain. The stream course is rocky, and is marked by small aggradation flats and boulders.

Jerrara Creek follows a very broad valley after emerging from the hills, and falls from 1,900 to 1,800 feet before plunging into a ravine through which it falls to Bungonia Creek. On either side of this stream the ground rises gently to form a plain at 2,000 feet—the general level of the "Shoalhaven Plain" (Text-fig. 4). This surface extends southward past Bungonia, where it is drained by Spring Ponds and Bungonia Creeks, the former being entrenched nearly 150 feet in a broad valley at its junction with the latter. The course of Bungonia Creek is sufficiently varied to deserve special attention.

When the limestone belt is crossed above Bungonia at 1,900 feet, the stream flows in a mature valley in the 2,000 foot plain. The limestone is associated with

sandstone, quartzite, grit and shale, which rest on granite and dip westward from 10 to 20 degrees, forming a low bluff on the right bank. Entering the zone of intrusive rocks the valley becomes narrower, but the stream continues to fall gently in a wide, sandy channel to 1,860 feet at Bungonia bridge. Beyond here the valley broadens again, and continues through weathered granite past the junctions of Spring Ponds and Ryan's Creeks, the latter entering about 1,770 feet. Half a mile further down is a sharp bend to the north-west, and the stream falls 50 feet to an elevation of 1,710 feet through a narrow ravine cut in dense felsite. This entry into fresher and more resistant rocks is marked by a corresponding increase in the steepness of the valley sides, although the fall during the next mile is only 50 feet and the floor of the valley is 100 yards wide. At this stage the depth of entrenchment is almost 300 feet, but only the lower half is represented by very steep slopes.

There is a fall of 160 feet in the next half-mile through a narrowing and steepening gorge, which finally becomes inaccessible with precipitous sides when the stream has fallen to 1,600 feet. Above the junction of Jerrara and Bungonia Creeks there is a notable series of waterfalls on either stream, and the ravines above the falls are deep and exceedingly narrow. Below their junction the waterfalls continue, but the gorge has assumed a more usual "V" shape with a depth of some 1,400 feet above the eastern limestones. Where it crosses the main belt of (blue) limestone, almost the whole depth of the gorge is represented by a magnificent ravine with perpendicular sides, but it widens considerably towards the Shoalhaven. A mile below the limestone the stream makes an accordant junction with the Shoalhaven River somewhat below 450 feet above sea-level. In time of flood the power of these streams is enormous, but they only cut downwards and backwards comparatively slowly through dense and unweathered rocks. In the stream channels the rocks are smoothed and polished by the abrasive action of water-borne material.

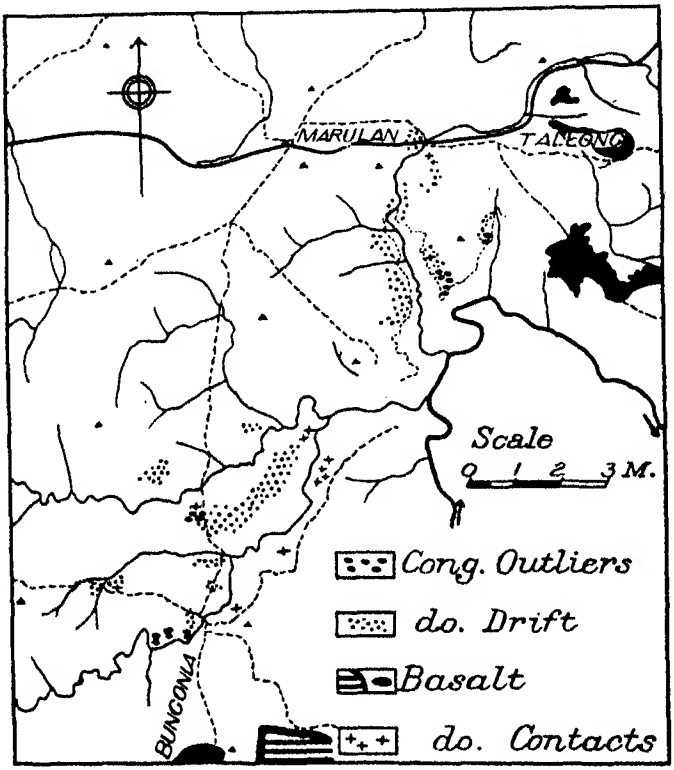
Ryan's Creek, a tributary of Bungonia Creek, rises near Chapman Trig. Station and follows the blue limestone northward through a broad U-shaped valley. Between the Inverary Park road and Bungonia Creek, a distance of 4 miles, it falls 130 feet. The ridge separating it from Bungonia Creek is capped with ancient sandstone, and has an elevation of 2,000 to 2,050 feet. Bungonia Creek cuts across the ridge from the west just above the junction of Ryan's Creek, and swings out of the limestone about a mile further on, so the strike ridge to the west of the limestone is cut in two by this stream, the eastern half continuing to the Lookdown. Near the Lookdown, the limestone belt is marked by a number of sink-holes and a series of small caves.

On the eastern side of this limestone belt, and separating it from the slopes leading to the Shoalhaven, there is a ridge composed of chert and jasper at an elevation of 2,100 to 2,150 feet. This extends southward from the head of Beck's Creek, and apparently represents part of the crumpled Ordovician formation although here, on its western side, the Ordovician zone is much less twisted and broken than is the case below Barber's Creek on the Shoalhaven. The general dip on this western extremity is westward. The limestone itself dips westward at 45 to 55 degrees, but at some places, as on the Inverary Park road to the east of Ryan's Creek, it rests upon slates dipping very steeply eastward.

Ridges leading from this line of hills towards the Shoalhaven exhibit level stretches at 1,900 feet as they approach the river. This terrace has, of course,

been greatly dissected, but it is a uniform feature on the western side of the river for some miles above the Lookdown, and might possibly be correlated with the eastern part of the valley of Jerrara Creek or the basalt-filled valley of Caoura.

This part of the Shoalhaven Valley is, then, a plain at 2,000 feet, in which broad, mature valleys have been cut to a maximum depth of 200 feet. It has been trenched by the canyons of the Shoalhaven and tributary streams, the latter of which are now cutting back from the main gorge.



Text-fig. 8.—Map showing conglomerate relics, contact quartzites and basalts. Compare with Text-fig. 2.

c. Conglomerates and Contact Quartzites (Text-fig. 8).—The plain has two features which make it especially noteworthy in the remains of pebble conglomerates and the presence of occasional glassy quartzites similar to those found in contact with the Caoura basalts. The quartzites have already been mentioned, but further details might not be amiss. The principal occurrences are:

1. Capping a hill 700 yards NW. of Bungonia Trig. Station. Elevation 2,000 feet. Thickness 10 feet. Extent (approx.) half an acre.
2. On Bungonia-Marulan road, 800 yards south of Jerrara Creek. Quartzite and indurated conglomerate on the hillside at 1,950 feet cover about an acre and a half. The covering is superficial, and overlies white clay from porphyries.

3. To the east of Bungonia Creek between 1,870 and 1,970 feet. The occurrence is about the western edge of the limestone a mile SW. of the Lookdown. The meridional length of the occurrence is 500 yards, and the maximum width 300 yards. The thickness is doubtful, but must be several feet in places.
4. On the ridge between and above Bungonia and Jerrara Creeks at 1,950 feet. The outcrop has a length of 600 yards, but the width rarely exceeds 20 yards. It is replaced towards the south by quartz pebble drift.
5. On hillsides to the west of Ryan's Creek, and an erratic on the plain to the east. Elevation 1,830 feet. These pieces are probably the product of weathering from higher levels, the material on which they originally rested having been dissolved away.
6. Pieces of silicified conglomerate in the valley of Spring Ponds Creek on the Goulburn-Bungonia road. Elevation 2,010 feet. The occurrence is not extensive.

All of these occurrences are purely surface features developed under favourable conditions, either on sandy soil, sandstone or weathering conglomerate. They are entirely distinct from the partially altered sandstones found near the top of the granitic intrusion, or the massive quartzite contact series found on the sides of the intrusion at a considerably lower level. A fine example of the latter is a greenish-quartzite bluff 100 feet high which overlooks the junction of Bungonia and Jerrara Creeks from the north-west.

It seems certain that the six occurrences noted are similar in origin to those near the Caoura flow—they owe their existence to basalt flows which have passed over the old land surface, here about 2,000 feet. Their closeness to ancient streams, together with the presence of elevated basalts at Inverary Park with a base at 2,060 feet overlooking the valleys of Ryan's and Bungonia Creeks, adds weight to the suggestion that these quartzites were associated with now-eroded basalt flows, and mark a part of the late Tertiary land surface.

Turning now to the conglomerate relics, we find them to be much more widespread, although the greater part is probably a surface screening only which has come down from disintegrated strata at a somewhat higher level in the natural process of vertical wasting. The principal occurrences are:

1. Conglomerate strata and drift on the divide between Jerrara Creek, on the one hand, and Spring Ponds and Bungonia Creeks on the other. The elevation varies from 2,010 feet to 1,950 feet (and may be even lower) on the Bungonia-Marulan road. Portion of this material at the lower level has been indurated. The remainder rests on porphyritic rocks and appears to be horizontal. It contains pebbles of white reef-quartz, brown and grey quartzite, grey chert, jasper and quartz-porphyry—all locally derived material. The pebbles are somewhat rounded, and their major diameter varies from one to six inches. This drift continues northward along the ridge between 1,950 and 2,000 feet, and extends over a length of three miles and a half. Similar material is found on the opposite side of Spring Ponds Creek at a similar elevation.
2. Pebble conglomerates are found above Bungonia Creek at 1,960 and 2,030 feet. They are ferruginous, and contain quartz, sandstone and quartzite pebbles with a diameter up to 8 inches. In general they are well rounded and the material, on the whole, resembles that found south-west of Ballanya Trig. Station. The surface upon which they rest is of slight relief, and consists of decomposed granite overlooking the left bank of the stream a short distance below the western limestone belt.

3. Pebble beds are found at Spring Ponds Creek on the Goulburn-Bungonia road at an altitude of 2,000 to 2,020 feet. This material occurs near the junction of the two head-streams of Spring Ponds Creek, and at first sight looks like a bank of stream drift. Closer examination reveals the presence of cemented pebbles and fine-grained sandstone containing small quartz pebbles and gravel in places. A distinct horizontal bedding is visible. The larger fragments and pebbles are of quartzite, and the latter are ellipsoidal in shape, being unlike the rounded fragments or pebbles of similar rock found in the modern stream beds of the tableland or in the gorge of the Shoalhaven.

The conglomerate and drift about the 2,000 foot level would appear to be distinct from the base of the Permian series, which are found with some thickness on the other side of the Shoalhaven, where they form the surface of the tableland rising from 2,000 feet to an altitude in excess of 2,400 feet. Continuing northward from these pebble occurrences, we find similar conglomerate relics existing to the south-west of Ballanya Trig. Station, and on either side of Barber's Creek at an elevation of 2,000 feet. Woolnough (p. 786) recognized the latter and the screening near Bungonia Caves as being "Permo-Carboniferous", but they are confined to a plain level distinct from the rising base of the Upper Marine Series, and have no marked resemblance to the basal beds of those strata. (See also paper II of this series, when published). The following points may be recognized:

1. The Vessey and Jerrara ridges are old erosion scarps whose bases have been exposed by the removal of newer sediments. Presumably there has been some retreat of their outer edges.
2. The pebble drift and conglomerate extending from Bungonia to Tallong form part of late Tertiary deposits, and the more southerly relics project into ancient indentations, through which streams now flow. This must be taken as a tentative conclusion only, in the absence of definite palaeontological evidence.
3. The western limit of the Permian series is marked by the lines of high residuals, which can be compared with Mts. Walker, Flaherty, Lambie and Gangerang Range in the Cox Valley (Craft, 1928*a*).
4. The 2,000 foot level to the south of the Barber's Creek system represents a peneplain of Tertiary, and possibly of pre-Permian age which has been exposed again by more recent erosion. A similar level continues into the newer strata to the north, and extends over the eastern part of the Wollondilly basin (Craft, 1928*b*) and is, therefore, an erosional feature developed at a regionally constant base-level.
5. It will be noticed that there is no mention of faulting as a possible explanation of the high western ridges. There is no physiographic evidence of faulting in this area, as the description of the "residual ridges" will have shown. Likewise it is not suggested that the various top points of the residual ridges represent relics of ancient peneplains, as the gradual weathering of the post-Devonian folds is amply sufficient to account for the isolated and exceptionally high masses. The highest level to give a peneplain impression is that at 2,500 feet, which is comparable with the residuals in the Tallong area and the eastern Wollondilly at 2,350 to 2,400 feet.

The existing land forms in the Bungonia Creek system may be correlated with those around Tallong, again using 2,200 feet as zero:

Locality or Feature.	Cycle or Part Cycle.	Elevation.	Age.	Remarks.
Residuals	Ancient	+ 500′	Permian	Probable.
Ridges, Upper Jerrara Creek	1	+ 300′	Pre-basaltic	Doubtful.
Beck, Morris and Cow-hole Ridges	2	0	Pre-basaltic	Depends on correlation of land forms in horizontal and folded rocks. Doubtful because of closeness to Shoalhaven Plain.
Shoalhaven Plain	3	− 200′	Pre-basaltic	Extended very little in more modern times.
Higher Terrace, Upper Jerrara Creek	3	− 100′	Pre-basaltic	
Valleys of Jerrara, Spring Ponds and Bungonia Creeks ..	4	− 300′	Post-basaltic	Average value for middle part of plain section.
Deep Gorges	5	− 1700′	Post-basaltic	Extreme value.

vii. *The Shoalhaven Gorges.*—The upland country supplies the most valuable physiographic material, but the deep gorges are also instructive. Between Bungonia Creek and a point opposite Caoura Trig. Station the river falls from 420 feet to approximately 350 feet. It flows in a narrow, rocky channel up to 60 yards in width, but where conditions are favourable lateral erosion has given flats or terraces on the concave bends which are covered with old flood-drift. The flood terrace rises to 60 feet above the river-bed immediately above very sharp turns, and consists of rounded pebbles up to 2 feet in diameter overlain by smaller rock-fragments and, in places, by a superficial covering of sand. In the actual stream-course the nature of the boulders found is largely controlled by the tributaries. Near Bungonia Creek the pebbles are small and consist largely of limestone and slate brought down by that stream and the river itself. Barber's Creek rolls huge boulders of granodiorite up to 4 feet in diameter into the river bed, and these constitute the greater part of the stony material during the next four or five miles. In time of flood these masses move along the rocky channel and form a great mill, which grinds and crushes all the smaller and softer material washed down by the torrent.

The lateral movement of the river has been greatest at the incised meander below Barber's Creek. Terraces exist 40 feet above the river, and consist of granite pebbles covered with a drift of soil which has, in times past, been cultivated (MacCallum's selection). Some 400 yards below Digger's Creek on the left bank relics of similar material are found 80 feet above the river. Here the river is diverted to the right by a quartzite bar and this, combined with a

sharp left-hand turn immediately below, has resulted in the piling up of the highest modern terrace on the right bank immediately above the bar.

Despite its great drainage area (2,400 square miles above this point) the normal flow of the river is quite small, although most of the channel is rendered dangerous by the presence of great boulders.

In considering the sides of this gorge, we are at once struck by the linear cliff lines between Digger's and Bullangalong Creeks on the northern side of the river. These walls illustrate the slowness with which massive horizontal layers in the top position are attacked, provided that they are not underlain by excessively weak strata. Passing upstream, the great bay eroded by Digger's Creek has already been noticed and, continuing southward along the main gorge from that point, the gorges torn in the main slope by Bungonia, Beck's and Spring Creeks make that section difficult to traverse. Again the weakness of the Ordovician structures is shown, as the crumpled and closely jointed strata are readily torn away by stream action. The shales and slates are susceptible to atmospheric influences and crumble readily on exposure, thus undermining the more resistant quartzites. On the eastern side the capping of horizontal sandstone has protected the tableland to some extent, but the absence of notable streams in this part has also retarded the dissection of the canyon sides. Further up the river this condition does not apply.

The rapidity with which the Shoalhaven has cut its canyon is illustrated by two facts. The slopes are very steep, being often inclined more than 35 degrees to the horizontal, even though they consist of easily-eroded strata. Evidently there has not been sufficient time for them to have been reduced much. Powerful tributaries, such as Barber's and Bungonia Creeks, have not been able to extend their gorges very far back into the tableland (Text-fig. 10), also on account of this lack of time, although it must be remembered that both have come against hard and fresh rocks which offer great resistance to erosion.

This gorge represents the latest work of the river, and the rate of cutting by such a powerful stream must have been rapid, especially in the weak meridional section. The whole time taken in this work must have been only a fraction of that which has elapsed since the formation of the 2,000 foot level before the period of Pliocene basalt flows. Small tributary streams such as Ruse's Creek have not yet had time in which to take advantage of the extra grade given them by the cutting of this trench. The lower valley of the stream in question is now becoming trenched, and it is only a matter of time before the gorge now being eroded will drain such swamps as those existing on tributary "1".

It might be argued that the formation of the small mature system quoted could easily have taken place whilst the canyon was being cut. That would mean that purely vertical erosion would have to be checked effectively in order to allow the formation of the existing grades (Text-fig. 10), and the lateral widening of the valleys after these profiles had, in their essentials, been attained. This hardly explains why the purely vertical cutting from the gorge or downstream side is taking place quite readily now, and it makes the dangerous assumption that the sandstones on which the lower parts of the mature profiles are found are particularly resistant to erosion—an assumption for which I can see no justification.

There is one place where one might expect to see vertical cutting checked, thus allowing considerable lateral widening of the valley. In part of its course Tallowa

Creek has cut down to particularly hard and massive porphyries (shown as intrusive on Text-fig. 2), which are overlain by rather weak fossiliferous sandstone of the Upper Marine Series. The process of downcutting has continued without any appreciable widening of the gully, despite the highly resistant nature of the porphyries, in which the stream is now entrenched to at least 150 feet, and possibly more further downstream.

We would conclude, then, that whilst upland valleys such as those of Ruse's Creek are still approaching more mature forms where they are not actually being trenched by headward erosion, still their formation as essentially mature features must have antedated the cutting of a gorge of even limited depth by the Shoalhaven. If we grant that this canyon only forty miles from the present coast is a recently-developed feature, we necessarily admit that it has only been made possible by comparatively recent major changes in the pre-existing order, and the only change competent to produce such results is one involving considerable uplift of the land surface after a period of stability. This uplift would be required to be of the order of 1,000 feet.

Land Forms.

Now that the greater part of the information is at our command, it becomes possible to survey the area broadly as a whole, and to collect the scattered conclusions which have already been reached. We shall begin with the upper surfaces and work downwards.

i. *Residuals and the Upper Tableland.*—The presence of sandstone residuals in horizontal rocks rising to 2,350 feet points to the existence of an old, high plain. The existence of similar and higher masses in the eastern part of the Wollondilly basin extends the area of such occurrences northward and, in fact, a considerable part of the Blue Mountain Plateau is involved.

Considering the Tallong-Bungonia area only, it is clear that not only is a previous higher level indicated, but that sedimentary strata of some kind must necessarily have existed over the present 2,000 foot level, giving it a surface of the order of 400 feet higher than at present. We might assume that the Shoalhaven Plain previously existed at an altitude higher by 400 feet than it does at the present day with respect to the upper surface of the more northerly sedimentary rocks, but such an assumption would only be justified in the light of some positive evidence, of which there is none at present. It would involve the postulating of differential uplift from north to south—an idea which seems to be contradicted by the uniformity of the 2,200 and 2,000 foot levels over wide areas in this region.

High residuals such as Vessey Trig. would appear to have existed several hundred feet above the maximum height of the newer sedimentary strata, in which case they would be strictly comparable with Mt. Walker, at Lithgow, which rises 600 feet above the highest sediments which rest on its northern side. Other similar places in the Cox Valley have already been cited. If the eroded Permian series about Ballanya Trig. Station were restored, it would be entirely covered, as residuals of the newer sandstones in the vicinity rise to the height of its crest. Its survival to the present day is due to the fact that it has been protected by the overlying strata, now removed.

ii. *Valleys of the Tableland.*—Defining the tableland proper as that surface now existing about 2,200 feet, we find that erosion has progressed in the tableland surface causing a widespread reduction of the order of 200 feet. That a

considerable part of this reduction was accomplished before the period of basalt flows is shown both in this district, and northward in the Wollondilly area. Valleys eroded down to this level have been filled with basalt, some of the most notable examples being in the Moss Vale district. As the result of more recent erosion, a good deal of this basalt has been removed. The 2,000 foot level has been re-established and extended considerably, especially in the shales and sandstones to the north-east of the Tallong area. Proceeding southward over the Shoalhaven Plain, we do not see any reason for stating that this plain surface is essentially a post-basaltic feature: our most reliable indications are to the contrary, and indicate considerable age for this feature.

Unfortunately it has not yet proved possible to investigate the area lying to the east of the Shoalhaven River and towards the coast, but it appears to be an inclined plain rising from 2,000 feet near the river to 2,400 feet some 7 miles further south. The rise continues southward to the Sassafras and Currockbilly Ranges.

More recent erosion has resulted in the formation of shallow valleys below the general level of the Shoalhaven Plain and around the edge of the Caoura basalt flow. This would appear to antedate the cutting of the modern gorges.

iii. *Gravels and Stream Capture.*—The great "elbow" of the Shoalhaven River near Tallong, when considered in connection with the long northerly course of the river, has led to the suggestion of capture. Woolnough and Taylor postulated a former Shoalhaven-Wollondilly stream flowing northward past Tallong before the plateau was raised to its present elevation. According to this hypothesis the Shoalhaven below Tallong has been reversed by capture from the direction of the coast, and previous to this capture streams such as Kangaroo River had flowed westward to join the old main stream at Tallong (see Taylor, 1918, p. 151). The various writings of Taylor make it clear that he accepted this view as having been proved, but the field evidence originally adduced to support this view is not at all convincing.

If one accepts the view that a "normal" stream and its tributaries should have a "dendritic" or branching-tree pattern, such an elbow as that of the Shoalhaven at Tallong is abnormal, and requires a special explanation, such as one involving stream capture. Taylor accepted this view (1911, p. 8), and cited Kangaroo River, a tributary of the lower Shoalhaven, as indicating a former westward flow of the whole system before the formation of meridional streams such as the Wollondilly (*ibid.*, fig. 18c). He envisaged three main stages. First, streams such as the Shoalhaven and Mulwaree Creek flowing westward to the Abercrombie-Lachlan system. Second, these streams being diverted northward by a meridional monoclinal fold. Third, the combined westward and northward-flowing streams on the coastal side being diverted eastward by capture from the coast following the uplift of the modern tableland. I propose to consider this third stage specifically.

Field evidence in favour of an ancient stream channel across the highlands at Tallong depends on a continuous valley leading from above Digger's Creek to a gap in the Shoalhaven-Wollondilly divide near Shepherd Trig. Station, on the presence of stream gravels along the floor of this valley, and on the impossibility of the gravels having been derived locally.

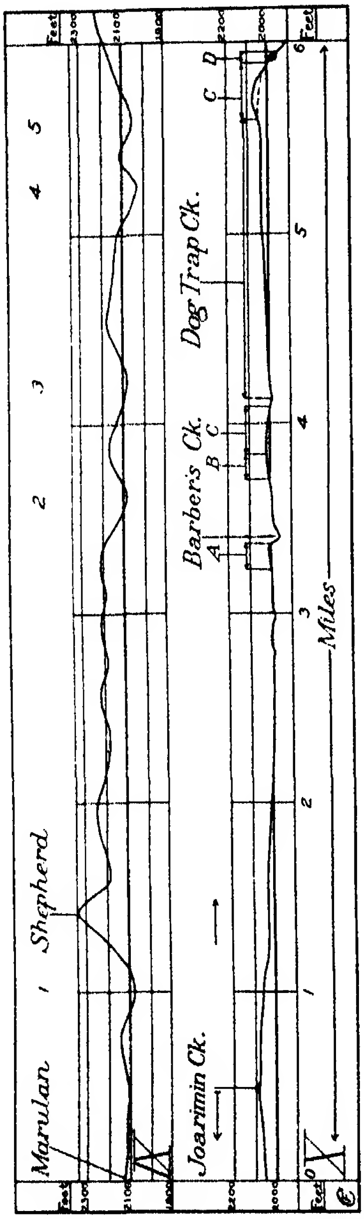
In considering the gravels, whose general disposition is indicated in Text-figs. 8 and 9 and on Plate vi, it must be borne in mind that they lie immediately

off the edge of the Permian conglomerates, which contain specimens of all the older rocks in the district, some of which have been brought from a distance. Masses of quartz-porphyry found at the head of Tallowa Creek, for instance, are six miles from the nearest stratigraphically higher porphyry at Marulan. A summary of the various occurrences of gravel and pebbles is instructive.

Locality or Occurrence.	Altitude at Base.	Thickness (in feet).	Rock Types.	Size of Pebbles.	Shape.
Permian Conglomerate	Maximum 2,150 ft.	Variable	Varieties of quartzites: cherts, jaspers, porphyries	Max. 3 ft.: 3 in. to 9 in. diameter	Angular to ellipsoidal
East of Ballanya	1,950 ft.	60	Brown quartzite and sandstone. Slates and cherts	2 ft. maximum diameter	Angular to ellipsoidal
Viaduct, Barber's Creek	2,000 ft.	15	Quartzites, jasper chert, quartz, indurated conglomerate	Maximum 3 ft. Generally 3 in. to 8 in.	Sub-angular or rounded
600 yards SE. of Viaduct	2,000 ft.	Surface	Silicified conglomerate and sands *in situ*	To 3ft.	Masses on ground surface
Eastern side Dog Trap Ck.	2,000 ft.	Surface	Brown quartzite	9 in.	Ellipsoidal
Dog Trap Ck.	1,960 ft.	In stream channel	Brown quartzite	To 18 in.	Sub-angular

The gravels east of Ballanya are apparently an outlier of the Upper Marine Series, and are described under the heading "Jigger's Creek". Those at the viaduct are outwash on to the flood plain of Barber's Creek, which stream now flows at a lower level and does not reach this height. The occurrence of indurated conglomerate indicates that the gravels have been derived, in part, from the vicinity of the basalt flows. Some of this material is found *in situ* near the viaduct. The quartz pebbles to the east of Dog Trap Creek are just off the lower edge of the conglomerates (Text-fig. 2), whilst the stream channel contains boulders of granodiorite weathering *in situ*, and quartzite which may be derived either from the conglomerate or the older rocks upstream. This latter is only mentioned because it has been referred to as "redistributed stream gravel".

With regard to the stretch between the viaduct and the gap near Shepherd Trig., Woolnough and Taylor (p. 550) refer to "recent wash from the hills, overlying the old river gravels". Supposing that to be the case, the level of the gravel would be below 2,000 feet, and it is not the case towards the main road, where an undulating surface of normally weathering granite is exposed. On examining the gap to the west of Shepherd Trig. Station, it is found to exist at 2,080 feet, and outcrops of granite exist within 20 yards of the lowest part of this gap on either side, and at much the same level. Recent erosion on the southern side has disclosed 5 feet of sandy wash overlying clay, the latter containing rounded pebbles of weathering granite. Small fragments of quartz are found at intervals over the granite surface, and comprise some of the drift from the sedimentary rocks forming the hill of Shepherd Trig.



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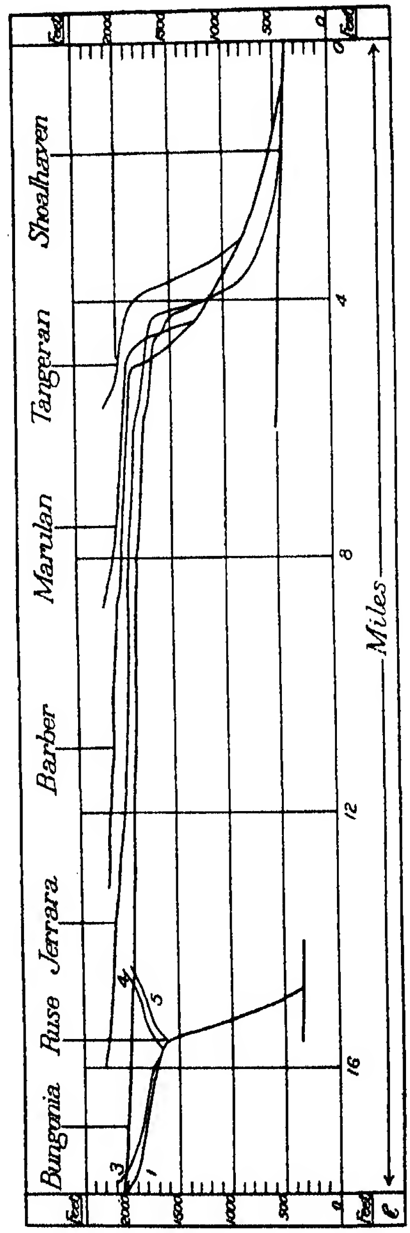

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Text-fig. 9.—IX shows a high-point line on the northern divide of Barber's Creek. Where necessary, short projections have been made on to the line shown on Plate vi to get the height of the actual divide. X is a profile from the east of Ballanya Trig. to Joarimin Creek. A = stream drift; B = contact quartzite; C = conglomerate drift; D = Upper Marine conglomerate above Digger's Creek. Vertical exaggeration = 5·9.
Text-fig. 10.—Profiles of the main streams. Note the predominance of the level about 2,000 feet, and the steep fall of the revived streams from the tableland. Ruse's Creek is shown separately for convenience. Vertical exaggeration = 8·8.

Now consider the two profiles IX and X (Text-fig. 9). The latter shows the ground over which the hypothetical ancient stream is supposed to have flowed. Its elevation would vary from 1,950 feet at the base of "D" to 2,040 as a minimum on the divide of Dog Trap Creek. A steady fall leads to the base of the gravels at the viaduct at 2,000 feet, whilst a sustained rise leads to the gap near Shepherd Trig. This curve does not represent the thalweg of a stream which flowed from "D" to Joarimin Creek as Woolnough and Taylor suggested, but it does represent a normal profile for streams flowing to such an ancient main stream as Barber's Creek.

Profile IX shows part of the northern divide of Barber's Creek. The deepest gaps are those at the head of Marsh's Creek, but Uringalla Creek as a whole has been very active in breaching its divide after having attained maturity. This curve demonstrates that the gap "1" near Shepherd Trig. is to be regarded as a normal feature of the landscape and, in view of the weathered granite exposed at this point and the proximity of the edge of the horizontal rocks, its presence is to be expected. There is no justification for assuming that a main stream flowed through this gap at one time when similar features exist at a lower level in the same divide.

A critical examination fails to reveal any field evidence in favour of a hypothesis of stream capture or of an ancient stream having flowed over this part of the land surface between the upper Shoalhaven and the Wollondilly. On the other hand, there is a considerable body of evidence which indicates that the present scheme of drainage has persisted since a time antedating the late Tertiary basalt flows.

The basalt-filled valley leading from Badgery's Lookout to Caoura, and existing below 1,900 feet, indicates a persistent eastern drainage over a long period, and discounts the idea that Kangaroo River flowed westward to Tallong at some time before the uplift of the present tableland. Corroborative evidence is found in the increasing amount of mature erosion as one goes eastward and in the appearance of incomplete cycles of erosion towards the coast.

The Shoalhaven Plain exists at about 2,000 feet, and would appear to be an ancient feature which has existed over a long period of time at a level below that of the sandstone tableland further north, and essentially below the divides between the Shoalhaven and Wollondilly systems. On either side of this divide similar topographic features are developed to levels below those of the divide itself. The level valley of the Wollondilly between Brayton (or Longreach) and Paddy's River at an elevation somewhat below 2,000 feet (Craft, 1928*b*), and the shallow valleys of the Bungonia Creek system incised in the 2,000 foot Shoalhaven Plain are cases in point. The latter especially is noteworthy, as it can probably be correlated with the small mature valleys of Ruse's Creek.

The ancient stream line as postulated by Woolnough and Taylor has left the wide lower valley of Barber's Creek out of the account entirely. W. R. Browne, in verbal communications to the writer, has stressed this, and has insisted that the intersection of the supposed with the actual stream line condemns the former, a conclusion with which I agree. It might be said that the upper Shoalhaven and the Wollondilly were once continuous by way of Barber's Creek, and that the lower part of the latter has been reversed by capture from the east. Apart from there being no field evidence to support this view, it is not necessary, and the objections cited above certainly apply to it equally with the original capture hypothesis.

In conclusion, we can state definitely that the present outline of the Shoalhaven River near Tallong represents its essential form since the development of the plain surface now at 2,200 feet; that the valley line between Digger's Creek and the gap near Shepherd Trig. Station does not represent the line of flow of a main stream, and that the idea of the Kangaroo River ever having flowed westward to or past Tallong must be dismissed. In considering the factors which may originally have determined the outline of the Shoalhaven River we enter the realms of more or less legitimate speculation.

iv. *Streams of the Area.*—The principal facts relating to the streams have already been disclosed, but they may be collected and summarized with advantage. As regards the actual profiles (Text-fig. 10), they are seen to be characteristic of revived streams. Barber's Creek flows at grade through its whole upper length. Jerrara and Bungonia Creeks flow at grade through the residual masses and over the plains before passing into narrow, level gorges without a great fall. They fall from these preliminary gorges in a series of cataracts to meet in a deep canyon. Their profiles show no disturbance such as one would find if their courses had been folded or faulted across (contrast Cox's River, Craft, 1928*a*).

The effect of the main stream is shown clearly by the steepness of the lower parts of these profiles. The Shoalhaven has reached grade rapidly, and by giving its tributaries the advantage of a great fall in their lower stages, it is enabling them to attack the tableland. The effective base-level of erosion is the level of the river where a tributary enters it. These streams contrast with those of the Cox, Grose and Colo systems of the Central Tablelands, most of whose tributaries have cut steep gorges right to their watersheds. The fact is emphasized that the last stage in the uplift of this more southern plateau was comparatively recent, so erosion of tributary gorges has not yet progressed very far. Erosion in the earlier stages of uplift had resulted mainly in the excavation of rather mature valleys, the greater part being done towards the coast.

Considering the actual shape of the streams, we are at once impressed by the great incised meander of the Shoalhaven below Barber's Creek, a feature which has been inherited from the original stream course at a higher level before the canyon stage began. Meanders on a much smaller scale are exhibited by Jerrara, Bungonia and parts of Barber's Creeks. In the first two cases the meanders persist right along the varying courses of the streams through residual ridges, over plains and, to a limited extent, in the gorges. In the residual country Jerrara Creek has inherited its meanders from the 2,100 foot terrace at least, as they are comparatively fixed in slight entrenchments at the present day. These circumstances agree with the remainder of the evidence, which points to a remote origin for these streams, even indicating that conditions to determine their origin were evolved about the time of the deposition of the Permian sediments. This only applies to the high western masses, which would appear to have supplied material for all of the newer sedimentary formations from the Permian onwards.

The lower part of the Shoalhaven flows some five miles to the south of the Hawkesbury Series, which appears to begin at Wingello, and continue eastward to the north of Tallowa Creek. A similar feature is shown by the Wollondilly River between Paddy's River and the Wanganderry bend, by the northward-flowing section of the Kowmung River, and by Cox's River from its junction with the Kowmung almost to its head. In each case the present edge of the Hawkesbury Series (Triassic) is of the order of five miles from the stream, and exists on one side only. It is suggested that these streams have a similar origin:

that the edges of the Hawkesbury Sandstone formation—itself probably of shallow-water origin—were loose and unconsolidated, and when the deposition of the Triassic strata was complete and the formation was first raised and exposed to the attack of the weather, the edges of the formation were readily eroded. Valleys so formed were occupied by the progenitors of the streams named, which flowed according to the local slopes to the sea. In time these streams established themselves and became permanent features of the landscape.

The basis of this idea has been current for a considerable time, and Taylor (1911, p. 14), suggests that the exposed soft "Permo-Carboniferous" strata favoured the development of the lower Shoalhaven, which is found about the present edge of the Upper Coal Measures. This suggestion is complementary to that repeated above which Taylor also recognized. It is as yet too early to attempt any explanation of the origin of the Shoalhaven above Barber's Creek, although its later development would doubtless have been favoured by the weak Ordovician structures which it has exposed. The supposed origin of the lower Shoalhaven is only to be taken as a supposition of reasonable possibility.

Soil and Water Supply.

An outline of the conditions of the soil and water supply of the area can be given both for purposes of physiography and economic geography. On the whole, the soil is of a sandy or gravelly nature. The conglomerate and sandstone tablelands near Tallong are rocky and hold little water. Valleys cut in them have a depth of soil up to 5 feet overlying pebble wash and this soil, in places, holds a good deal of water. These conditions give rise to swamps such as those found at the head of Barber's Creek and along its upper valley as far west as Tallong. The permanent water supply of Barber's Creek depends on these swamps, and is supplemented by soakage from the northern sides of the upland basalts. Drainage from the southern side of these latter areas passes into Tallowa Creek.

The basalts have a definite value in storing up water and releasing it gradually in dry times. The Caoura flow is divided into thin sheets which are split up by a series of close vertical joints. Water penetrates this readily, and is stored up in the cracks and interstices, with the result that small streams heading in the basalt are permanent, whilst those originating in nearby sandstone are liable to fail in dry weather. Water issuing from the base of the basalt is charged with minerals in solution; in dry weather its taste is unpleasant, but stock drink it readily enough.

Going westward and southward over the granite areas, we find a light sandy soil on the surface overlying clay subsoil. A good deal of water is stored in the surface layers, but it passes out readily during dry weather, so the normal flow of the streams in this part of the area is not so great as one might expect. They generally contain water, however, as sand beds in the rocky channels store a certain amount, and waterholes in the rocks or clay are fed by a slow percolation from the deep valley soils. The light surface favours rapid erosion after a dry spell during which the grass has been eaten off by stock or rabbits, but as this erosion is only very effective in country of such gentle slopes along the stream banks, the preservation of occasional trees on these provides an effective check, and helps to prevent waterholes which they shade from drying up altogether. Where all the trees have been cut away, the process of land destruction is

becoming progressively more rapid, and can only be checked by planting suitable trees and grasses in the weathering banks.

The residual ridges have light, deep soil in their valleys and along their lower slopes, but as this is derived mainly from quartzites and porphyries, it is of a sandy nature, absorbing a great deal of water and giving it up readily either to streams or to the atmosphere. The ridges themselves are stony and arid, and their steep slopes make a high run-off inevitable. In places where they are being cleared and stocked the removal of the little soil is only a matter of time. As the valleys are largely eroded in shales, slates and occasional limestones, they are marked by much gentler slopes and, where deeply-weathered soil has accumulated, a fair amount of water is retained and gives a small permanent soakage to the streams. On the whole the residual country is dry, although its porous soil combined with the fact that much of the country is still forested tends to reduce the violence of floods, and to retard erosion.

Taking the remaining land—that on the Shoalhaven side of the granites—we find that the limestones and associated slates produce deep soil in level valleys. This holds water fairly well, and is useful for agriculture over limited areas along Ryan's Creek. The sink holes towards the Lookdown at Bungonia discharge water through underground tunnels into Bungonia Creek. East of the limestone belt there is a series of chert, jasper, slate and quartzite ridges. These are close to the edge of the Shoalhaven gorge and the steep slopes, combined with the strongly-jointed nature of the rocks, render them almost useless for the storage of groundwater. This applies to the slopes of all the gorges, which are singularly dry and waterless. In very steep places even scrub will hardly grow.

The effect of these conditions in the area as a whole is to give streams which, although they flood after heavy rain, still continue to run freely for a month after the ground has been saturated. In dry summers all of the streams are likely to dry up, with exception of the head swamps and lower courses of Barber's Creek; Tallowa Creek, which flows in a deep and sheltered gully, and the streams originating in the basalts. Barber's Creek only ceases to run in its middle portion during exceptionally dry summers, but Stony, Jerrara, Marulan, Bungonia and Tangeran Creeks hardly flow during the greater part of summer and autumn, although they all have permanent waterholes.

There is generally enough water for stock but, from the viewpoint of erosion, the drying of the watercourses and their surroundings in the hot season is unfortunate, as the ground cracks and is broken by stock, and the light soil is carried away easily by rain which succeeds the drought periods.

On the imperfect evidence available it would be unsafe to say that the clearing and settlement of the country is causing streams to become less permanent, but it is certainly accelerating erosion in the mature highlands.

Physiographic History and Summary.

Looking at this part of the Shoalhaven Valley we find that it consists of crumpled Ordovician rocks overlain by newer Silurian (?) and Devonian strata, the whole having been folded into a grand arch, of which the western limb is exposed in the Tallong-Bungonia area. The crest or axis is represented at the present time by the linear outcrop of Ordovician strata along the Shoalhaven River between Nerriga and Tallong. The crest and eastern limb of this arch were cut away by erosion to form a peneplain, upon which the Permian strata were eventually deposited. This surface was warped or folded down to the

east and north-east, allowing a great accumulation of the newer sediments, but the western portion stood relatively high, and was flanked on the west by ridges of Devonian quartzites. Newer surfaces were built up by sedimentation within a few hundred feet of the crests of these ridges, and the older and newer strata have been subjected to erosion and denudation over long intervals of time. The history of the land forms may be thus summarized:

"Kanimbla Epoch" (Pre-Permian).—Folding of grand arch southwards. Formation of peneplain, with ridges to the west.

Permian.—Deposition follows subsidence, which was most pronounced to the east and north-east. Littoral beds in this area.

Triassic.—Deposition of Narrabeen, Hawkesbury and Wianamatta beds to the north-east.

Tertiary (provisionally).—Final development of modern stream systems, including lower Shoalhaven off the edge of the Hawkesbury Series.

Late Tertiary.—Earliest uplifts (?)—residuals of 2,350 foot level formed as the general surface was reduced to the modern 2,200 foot level. This peneplain existed near sea-level.

Uplift.—Erosion to a depth of 300 feet in plain, forming Shoalhaven Plain and associated levels. Erosion of Caoura Valley after further uplift.

Basalt flows (the "newer basalts").—These were considerably eroded, the lower plain was extended, and there was additional erosion towards the east, as at Ruse's Creek, and the formation of shallow valleys in the lower (Shoalhaven) plain.

Great uplift of the order of 1,000 feet in stages, resulting in considerable erosion and incomplete cycles of erosion towards the coast and a great removal of coal measure strata, but hardly affecting this area.

Erosion of modern gorges. Uplands in which streams have not been revived continue to progress slowly towards maturity.

In conclusion, it may be remarked that the views of Andrews (1910) and Sussmilch (1911-1922) regarding the development of the tableland surface are confirmed for this area, but the hypothesis of post-Tertiary stream capture advanced by Woolnough and Taylor is rejected.

Since this was written, a paper by G. F. Naylor on the drainage of the Marulan district has appeared. Working on the basis of Woolnough and Taylor's paper the writer accepts the hypothesis of stream capture, although he rightly rejects some of the earlier arguments in its favour. His arguments and conclusions, however, do not accord with a more detailed field examination, and many of them can scarcely be justified.

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EXPLANATION OF PLATES IV-VII.

Plate iv.

1. The Shoalhaven River at the junction of Digger's Creek. Note the terrace of detritus built up by the tributary.
2. View across the valley of Jerrara Creek, looking up Limestone Creek, a strike valley in limestone and slate. Vessey Trig. Station is to the right, and rises about 200 feet above the ridges on the left.
3. View down Jerrara Creek looking over Pearce's farm. The strike valley of the preceding view is in the foreground; a hard residual ridge is cut across by a consequent stream—Jerrara Creek—in the middle distance, and the Shoalhaven Plain is seen in the background. The most distant ridge is on the eastern side of the river.
4. The bed of Dog Trap Creek, about 600 yards above Barber's Creek. Note the fine wash resting on decomposing granodiorite. The smaller pebbles are of quartzite. This view is typical of the stream beds in the granite uplands.

Plate v.

Topographic Map of the Tallong District, eastern section. The Shoalhaven River is flowing between 300 and 400 feet above sea-level. Tertiary basalt flows are shown.

Plate vi.

Topographic Map of the Tallong District, western section. The main road and railway pass through Marulan. These maps are based on county and parish maps of the N.S.W. Lands Department, and topographic detail is by closed and corrected traverses, plotted originally on the scale of six inches to the mile. Vertical control by aneroid and Abney level.

Plate vii.

1. View from Warrima Trig. Station, showing Twin Trig. rising above the tableland at 2,200 feet with the head of Barber's Creek in the foreground.
2. The northern edge of the Caoura basalt flow, looking eastward. Basalt is in the foreground and to the right; the tableland at 2,200 feet is on the left and the scarp is one side of the pre-basalt valley steepened by modern erosion. Tallowa Creek flows in a gully to the left of the cleared basalt country.
3. The northern edge of Caoura basalt flow, looking eastward near Caoura station. Basalt banks are cleared in the foreground and on the right; the sandstone terrace, dissected by modern erosion, occupies the middle distance, whilst the tableland surface is seen in the distance.
4. The Shoalhaven River, looking upstream with the junction of Barber's Creek in the right background. View from above "McCallum's Selection".

FURTHER NOTES ON THE ORCHIDS OF THE SOUTH MAITLAND COALFIELDS, WITH DESCRIPTION OF A NEW *DENDROBIUM* FROM BULLAHDELAH.

By the REV. H. M. R. RUPP, B.A.

(Four Text-figures.)

[Read 29th April, 1931.]

I have given an account (These PROCEEDINGS, 1930, 413) of the autumn orchids of the South Maitland Coalfields and the present notes cover the winter and spring months, June to October, inclusive. One species, *Liparis reflexa* Lindl., was omitted from the autumn list, and may be recorded here with three belonging to the summer: *Sarcochilus Hillii* F.v.M., *Calanthe veratrifolia* R.Br., and *Dipodium punctatum* R.Br. Some of the autumn species are found flowering throughout the winter, but the only two to which I shall allude here are *P. ophioglossa* and *P. concinna*, a fairly obvious hybrid between these having been found in July.

Following is a list of the other orchids observed from June to October:

Dendrobium speciosum Sm.
aemulum R.Br.
gracilicaule F.v.M.
teretifolium R.Br.
striolatum Reichb. f.
Becklerii F.v.M.
pugioniforme Cunn.
linguiforme Swz.
Bulbophyllum Shepherdii F.v.M.
exiguum F.v.M.
Sarcochilus falcatus R.Br.
olivaceus Lindl.
Cleisostoma tridentatum F.v.M.
Cymbidium canaliculatum R.Br.
suave R.Br.
Calochilus cupreus Rogers
Robertsonii Benth.
paludosus R.Br.
Thelymitra ixioides Swz.
longifolia Forst.
nuda R.Br.
pauciflora R.Br.
sp.?
carnea R.Br.
Diuris aurea Sm.
sulphurea R.Br.
brevifolia Rogers?
Microtis porrifolia Spreng.
parviflora R.Br.
oblonga Rogers
Corysanthes fimbriata R.Br.
pruinosa Cunn.
Pterostylis nutans R.Br.
pedunculata R.Br.
curta R.Br.
mutica R.Br.
Mitchellii Lindl.
pusilla Rogers
var. *prominens*, n. var.
longifolia R.Br.
Caleana major R.Br.
Chiloglottis formicifera Fitzg.
Acianthus reniformis R.Br.
Lyperanthus suaveolens R.Br.
Caladenia testacea R.Br.
alba R.Br.
carnea R.Br.
caerulea R.Br.
Glossodia major R.Br.
minor R.Br.

The epiphytes in this list (*Dendrobium* to *Cymbidium*) occur chiefly in the ranges on the S. and W. borders of the area. I am positively assured, however, that a white-flowering form of *Cymbidium canaliculatum* has been found not far from Weston, my informant having secured a plant and brought it to flower in cultivation. Unfortunately this plant has been sold. It is now some fifteen years since I first heard of a white-flowering form of this orchid, but I have never succeeded in obtaining a specimen.

CALOCHILUS.—Fitzgerald's representations of *C. paludosus* and *C. campestris* are difficult to understand. Dr. R. S. Rogers (*Trans. Roy. Soc. S. Aust.*, xlii, 1918) has noted that the former is incorrectly figured; while the flower of *C. campestris* is shown with a coloured ridge connecting the two column-glands, a feature peculiar to Bentham's *C. Robertsonii*. The basal portion of the labellum is also shown as callose, but calli are only present in var. *grandiflora*. The figures cannot be reconciled with published descriptions of either plant (including those of Fitzgerald himself in Moore and Betche's Handbook), and it may be in part due to this difficulty that we have for many years in New South Wales been confusing *C. campestris* with a plant which is really Dr. Rogers's species *C. cupreus*. The following tabulation of certain salient points in the four New South Wales species may help others in determination:

C. cupreus.—Plant slender or often very robust, with many relatively small flowers. Labellum not greatly prolonged, yellowish with fimbriate margins and reddish-blue hairs sometimes rather scanty; basal portion with raised longitudinal lines of similar colour to the hairs. Column with a gland on each side at the base, with an irregular line of brown blotches between them, but no ridge. Anther long, like a duck's bill.

C. campestris.—Flowers few, larger than those of *C. cupreus*, in var. *grandiflora* much so. Labellum much prolonged, densely covered with reddish-blue hairs except towards the base, where it is quite smooth (but in var. *grandiflora* beset with calli) and without raised lines. Column with a basal gland on either side, not connected by a ridge or coloured line. Anther acuminate or at least long and tapering.

C. Robertsonii.—Flowers usually few, variable in size. Labellum much prolonged, densely covered with purple metallic-lustrous hairs, which towards the base are reduced to calli, and there is a callose swelling on each side. Column with a basal gland on either side connected by a coloured ridge. Anther short and usually blunt.

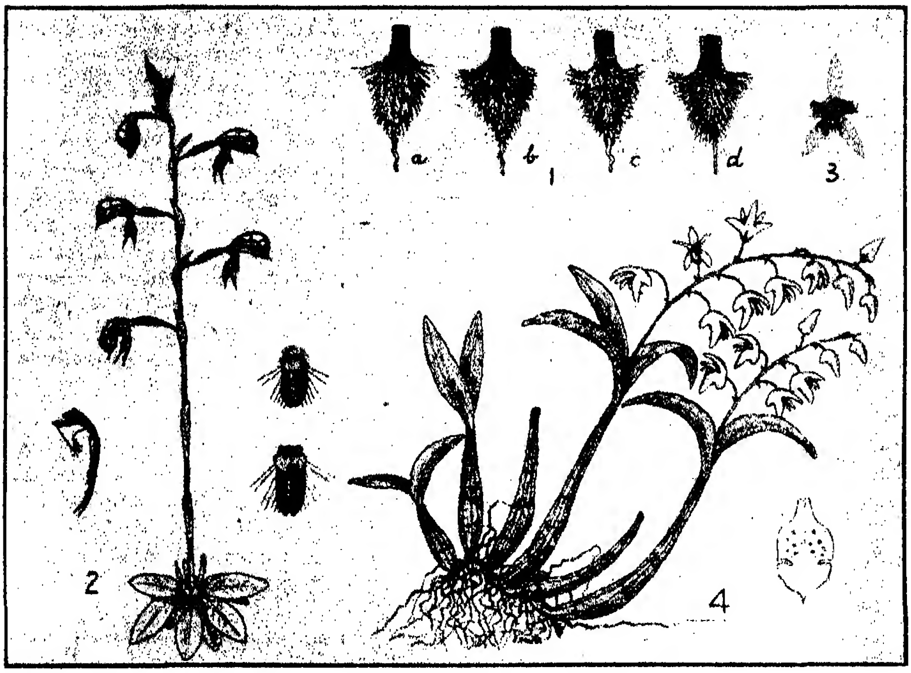
C. paludosus.—Plant often slender but sometimes tall with many flowers, which expand more widely than in other species. Labellum much prolonged, rather densely covered with long brilliant red hairs, which towards the base are reduced to calli, and there is a smooth, shining, much-raised plate on either side. Column devoid of basal glands. Anther short, thick, blunt.

All four normally have the apex of the labellum prolonged into a smooth, narrow ribbon, sometimes absent in *C. Robertsonii*. In *C. paludosus* it is often straight, in the others undulate. All except *C. campestris* are common on the coalfields.

THELYMITRA.—Near Weston a few immature plants were found in which the column appears to differ from that of any known species, but I was unable to secure sufficient good material for determination. *T. nuda* is the most abundant species. It is extremely shy, opening only for a few hours on warm, sunny days, when the pale-mauve flowers are very beautiful. The hair-tufts, usually almost

perpendicular, are of the same colour, or rarely whitish. *T. ixioides* occurs in a very slender form, occasionally 1-flowered. *T. pauciflora* and *T. longifolia* are uncommon, *T. carnea* is abundant.

DIURIS.—*D. punctata*, though abundant east of Maitland, has been searched for on the coalfields in vain. *D. aurea* is in great profusion, and very fine specimens have been seen. A very late form appeared in October, with rather



Text-figs. 1-4.

1. Labella of the four New South Wales species of *Calochilus*, enlarged and flattened out to display their distinctive features: *a*, *C. cupreus* with dark smooth ridges (commonly four) on the basal portion, and prominently fimbriate margins; *b*, *C. campestris* with a smooth, dark base obscurely lined with darker veins, hairs very undulate; *c*, *C. Robertsonii* with callose or very short hairy base, somewhat swollen on either side, hairs very undulate; *d*, *C. paludosus* with callose base and a smooth raised plate on either side, hairs scarcely undulate.

2.—*Pterostylis pusilla* var. *prominens*, n. var., with enlargements of labellum (right) and column (left). × 0·4.

3. Flower of *Caladenia caerulea* with three labella and a stigma-capped style.

4. *Dendrobium Kestevenii*, n. sp. (much reduced), with enlargement of labellum flattened out.

small flowers, and markings suggestive of *D. sulphurea*. It is probably a hybrid, and seems to be rare. *D. sulphurea* is plentiful in October; the markings on the labellum exhibit endless variety. The labellum of this species is described as having a single raised line, but in the majority of flowers examined in this area it is merely smooth and convex (above) from lamina to base, with no raised line at all. An interesting variety occurs near Weston, the flowers being large but

very attenuated, with lateral sepals much elongated. Near the Weston Soldiers' Settlement, I found a single specimen of a tall *Diuris* with 7 flowers corresponding to *D. brevifolia* Rogers. The leaves, however, were two only, and very long. The specimen has retained its colour after pressing, which is unusual in a *Diuris.* No other forms of *Diuris* were seen in the vicinity.

MICROTIS.—The three species listed are typical.

CORYSANTHES.—The type of country would lead one to expect this genus to be strongly represented, but only the two species listed have been seen, and neither is common. *C. fimbriata* is large and richly coloured.

PTEROSTYLIS.—I have already alluded to the appearance in July of an apparent hybrid, *P. ophioglossa* × *P. concinna.* This plant, of which about 20 were found, has the general appearance of *P. concinna*, with which it is associated, but the following points connect it with *P. ophioglossa*: (1) Flower rather larger than the surrounding *P. concinna*, with the characteristic forward "set" of *P. ophioglossa*; (2) petals bluntly truncate with inturned margins; (3) fork of the bifid labellum intermediate in character and just protruding from the sinus of the paired sepals; (4) column rather sharply bent; (5) stem (with two exceptions) bractless except immediately under the ovary. Robert Brown says of *Pt. ophioglossa*, "scapo medio ebracteato", and this peculiarity is not mentioned by most authors. It is a rule to which there are exceptions, but when a stem-bract does occur it is always low down.

Of the remaining winter-spring forms of *Pterostylis*, only two call for special mention, and they are of considerable interest. One, of which only two plants have been seen, I believe to be *Pt. Mitchellii* Lindl., which I have hitherto regarded as a species confined to the western parts of the State. (It occurs in other States also.) It seems certain that Fitzgerald was mistaken in the plant he figures as *Pt. Mitchellii.* Fitzgerald's plant is much closer to, if not indeed a form of, *Pt. pusilla* Rogers. Dr. Rogers has kindly lent me a photograph of Sir Thomas Mitchell's original specimens in the Hooker Herbarium at Kew, and it is not possible to reconcile these with Fitzgerald's plant. I also received from Dr. Rogers, a few years ago, two specimens labelled *Pt. Mitchellii* from Grangeville, S. Aust., which agree perfectly with two from Warialda in this State, which I had determined as Lindley's species. The coalfields plant also agrees with these save for one or two trifling details. The other coalfields *Pterostylis* alluded to presents some difficulties. I believed it to be quite distinct from any species hitherto described, and Dr. Rogers wrote that it was certainly not identical with any species known to him. Mr. W. H. Nicholls, however, maintained its identity with a Victorian form included under *Pt. pusilla.* It certainly does not conform to Dr. Rogers' description of that species (*Trans. Roy. Soc. S. Aust.*, xlii, 1918), but I am compelled to admit that I cannot separate the flowers from those of the Victorian plant referred to. The form of the plant, however, seems very distinctive. It is abundant near Weston in September and October, and in appearance is unlike any other *Pterostylis* I have seen. The plant varies in height from a few inches to a foot, and the flowers range from 1 to 13. They are alternate along the raceme on long ovaries and stalklets which incline to the horizontal, giving the plant the semblance of a candelabra. The colour is green or whitish with very pronounced red markings and veins, or often wholly red. I am disposed to think that this plant and the Victorian form with similar flowers should be separated from *Pt. pusilla* as variations of another species, unless Dr. Rogers should re-

describe *Pt. pusilla* to include them. The manner of inflorescence (of the coal-fields plant) is so striking that I have no hesitation in proposing that it be recognized for the present as a variety, *Pt. pusilla* var. *prominens*.

CALEANA.—*C. major* appeared in August, earlier than I have seen it elsewhere, and was still plentiful two months later. It does not seem to occur in colonies here as a rule. A form with flowers wholly golden-green has been found.

CHILOGLOTTIS.—Numerous flowering plants of *C. formicifera* were found in September at Rocky Glen near Mount Vincent.

ACIANTHUS.—*A. reniformis* is very common, and typical. A plant found by Miss D. Watson has two perfect flowers united "back to back" on a common pedicel.

LYPERANTHUS.—*L. suaveolens* is very common, both red and pale-green flowers being in evidence. Often very tall, 2 ft.

CALADENIA.—*C. alba*, *C. carnea* and *C. caerulea* are all in very great profusion; *C. testacea* is less common. *C. alba* exhibits many variations, and some of the forms are extremely beautiful, notably one with reddish-purple lateral lobes to the labellum. Hybrids with *C. carnea* seem to be indicated by the presence of red bars on the column or the labellum. *C. carnea* itself shows little variation from the type. *C. caerulea* is exceptionally vigorous. For the first time I succeeded in finding a specimen bearing two perfect flowers. A most abnormal specimen was found by my son, Mr. Arthur Rupp, the paired petals being transformed into a second and a third perfect labellum. The three sepals are quite normal, but the column is represented by a slender style capped with a stigma; a loose purplish structure almost surrounds it at the base.

GLOSSODIA.—*G. major* and *G. minor* are both abundant, the latter especially so. Hybrids occur, and the white-flowering form of *G. major* has been found.

DENDROBIUM KESTEVENII, n. sp. Text-fig. 4.

Caules in saxis serpentes, cum radicibus multissimis. Pseudobulbi striati, ad bases turgidi, 5–20 cm. longi. Folia lanceolata 3–4, ad pseudobulborum apices, 5–8 cm. longa. Racemi inter folia, 10–24 cm. cum floribus 4–14. Flos albus vel pallidus, saepe puniceo tinctus. Sepala lata, 2 cm. longa, calcar saepe obtusissimum. Petala sepalis angustiora. Labellum latissimum, 15 mm. longum, mucronatum, cum notis puniceis vel purpureis. Columna turgida.

Stems creeping on rocks, with densely matted roots. Pseudo-bulbs grooved and jointed, swollen towards their bases, 5–20 cm. in height. Leaves 3 or 4, lanceolate, at the tops of the pseudobulbs, 5–8 cm. long. Racemes emerging between the upper leaves, 10–24 cm. long, with 4 to 14 flowers. Flower white or pale-cream, often tinted pink or mauve. Sepals broad, only 2 cm. long, the spur under the lateral pair prominent but often very blunt. Petals narrower than sepals. Labellum, when flattened out, very broad, 15 mm. long, lobed like that of *D. speciosum*, and splashed with pink or purple, mucronate at the straight or slightly recurved tip. Column very thick.

This very beautiful orchid was sent to me in September, 1930, by Dr. H. L. Kesteven of Bullahdelah, whose sons had discovered it on the rocks of the eastern side of the Alum Mountain. A little examination served to make clear its close relation to *D. speciosum*, while some features suggest some connection with *D. Kingianum*. As both these species are common on the Alum Mountain, it is

quite possible that cross-fertilization between them produced the subject of this description; but from Dr. Kesteven's account of it there can be little doubt that it is well established independently. It would certainly not be recognizable as a variety of either, and it appears to be well deserving of specific rank. The flowers do not expand quite so widely as those of *D. falcorostrum*, and are not quite as large, yet at first sight it instantly suggests that species. This species is quite a notable addition to our orchids. As far as I can judge from the large mass of the plant sent to me, the stem quite definitely creeps over the rocks. The pseudobulbs resemble those of *D. speciosum* in miniature, being shorter, more robust, and more strongly grooved than those of *D. speciosum* var. *gracillimum*. Relatively to the size of the plant, the flowers are much larger than in any form of *D. speciosum*. The shape of the spur, the broad, short sepals, and the mauve tints occasionally present, suggest affinities with *D. Kingianum*. The perfume is certainly not that of the Rock Lily.

ON BARIDIINAE (CURCULIONIDAE), MOSTLY FROM NEW GUINEA.

By Arthur M. Lea, F.E.S.

(Thirty-seven Text-figures.)

[Read 27th May, 1931.]

Comparatively few species of this subfamily have been recorded from New Guinea and adjacent islands; but they are probably as numerous there as in tropical America; some of them are of comparatively large size and brilliantly metallic, although the majority are rather small and deep black, with or without white markings.

Baris.

Germar, Ins. Sp. Nov., 1824, p. 197.

The majority of Australian species belonging to the Baridiinae have been referred to *Baris*, and no doubt they would form material for several genera; some of the species which I also here refer to *Baris* may eventually be considered as worthy of generic rank; but in a genus so abundant in species, many of which are closely allied, with species diverging in many directions, it is not desirable to propose new genera unless they possess very distinctive features.

Pascoe (*Ann. Mus. Civ. Genova*, 1885, p. 292), in dealing with the weevils of the Malay Archipelago, said "*Baris* as it stands at present, is a group of many genera", and this is still the case.

Baris gibbicollis, n. sp.

♀. Black, shining. Parts of under surface and legs with short, white setae. Rostrum about one-third longer than prothorax, sides with moderately coarse crowded punctures towards base. Prothorax with basal width slightly more than median length, middle near apex rather strongly elevated; with fairly dense punctures of moderate size on disc, becoming slightly larger and denser on sides. Elytra elongate-cordate, distinctly wider than prothorax, a shallow depression at basal third and another beyond the middle; a fairly large obtuse tubercle crowning each side of the apical slope; sharply striate, the striae with punctures of moderate size, becoming rather small about middle; interstices with fairly strong punctures about apex and sides, a few smaller ones about base. Under surface with fairly dense punctures, coarser on side pieces of mesosternum than elsewhere. Front coxae fairly close together, front femora minutely dentate, the others moderately dentate. Length, 6·5–7·0 mm.

Aru Island (H. Elgner); New Guinea: Manumbo (Madang district).

A large species, very distinct by the bituberculate elytra and gibbous prothorax. *B. bituberculata*, from Torres Straits, is a much smaller species, with very different prothorax; several other species have the elytra slightly undulated owing to the transverse impressions, but their prothorax is not gibbous.

Baris porosterna, n. sp.

♂. Black, shining.

Rostrum slightly longer than prothorax, rather strongly curved; with crowded and fairly strong punctures on sides towards base. Prothorax moderately transverse; with fairly dense and sharply defined punctures of moderate size, becoming larger and crowded on sides. Elytra subcordate, not much wider than prothorax; with sharp striae containing deep-set punctures. Under surface with crowded punctures except on parts of abdomen; basal segment of abdomen distinctly impressed along middle. Front coxae rather widely separated, femora distinctly grooved and feebly dentate, tibiae with upper edge gently incurved to middle. Length, 4·5 mm.

Aru Island (H. Elgner); New Guinea: Astrolabe Bay (Dr. W. Horn, from — Rhode).

In appearance approaches several species of *Myctides*, but the rostrum is not bearded. On the prothorax the punctures are more or less confluent on the sides at the apical third, giving the surface there a notched appearance, as on *B. latericollis*. There is a row of minute punctures (scarcely visible from most directions) on each elytral interstice, but their only distinct ones are on the base and sides.

Baris punctivaria, n. sp.

♂. Black, shining. Front tibiae with a few dark hairs fringing the apical half.

Rostrum slightly longer than prothorax; with crowded punctures of moderate size on basal sides. Prothorax slightly transverse, sides gently decreasing in width to beyond the middle, and then strongly to apex; with numerous, but not crowded, and rather small punctures on disc, becoming larger on sides. Elytra elongate-cordate, not much wider than prothorax; with two shallow transverse impressions, causing the surface to appear faintly undulated; with sharply defined striae containing small, deep-set punctures; the interstices with very minute (almost invisible) ones, except for a few about shoulders. Under surface with fairly large punctures; middle of basal segment with a wide, shallow depression, continued on to metasternum. Legs fairly long, front coxae rather close together, femora feebly grooved and slightly dentate. Length, 5–6 mm.

♀. Differs in being slightly wider, rostrum thinner, prothoracic punctures distinctly larger, elytral interstices with fairly distinct punctures, although still small, abdomen evenly convex and legs somewhat shorter.

New Guinea: Wareo (Rev. L. Wagner); Papua: Mount Lamington (C. T. McNamara), Bisiatabu (Rev. W. N. Lock).

Fairly close to the preceding species, but slightly narrower, and elytra distinctly, although not very strongly, undulated. The sexual difference in size of the prothoracic punctures, and those on the elytral interstices, is quite conspicuous, and appears to be constant (there are eleven females before me, but only two males); on a female from Mount Lamington the punctures are fairly strong on the elytral interstices. On all of them the elytral striae are somewhat wider on the apical slope than about the middle. There is a short shallow groove in the front of the prosternum, but it is difficult to see it before the head is removed.

Wareo and Hudewa are in the Finsch Haven district, Bisiatabu is a mission station near Port Moresby.

BARIS ATROPOLITA, n. sp.

♂. Black, shining.

Rostrum slightly longer than prothorax; with crowded and fairly large punctures on basal sides. Prothorax moderately transverse; with numerous but not crowded punctures of moderate size, becoming larger on sides. Elytra oblong-cordate, not much wider than prothorax; with two feeble transverse impressions; with sharply defined striae containing small punctures, but these very small or absent posteriorly; interstices with a few small punctures about base. Under surface with dense and fairly large punctures, becoming small on most of abdomen, basal segment shallowly depressed along middle. Front coxae moderately separated; femora slightly grooved, each with a small acute tooth and some minute denticles. Length, 3·0–4·5 mm.

♀. Differs in having rostrum thinner at base and slightly longer, abdomen rather strongly convex, and legs somewhat shorter.

New Guinea: Wareo (Rev. L. Wagner), St. Aignan (Dr. W. Horn, from A. S. Meek); Papua: Mount Lamington (C. T. McNamara), Bisiatabu (Rev. W. N. Lock).

Fairly close to the preceding species, but the average size is smaller, the depression on the abdomen is shallower, the femora are more acutely dentate, and there is no fringe on the front tibiae of the male, the punctures are also not sexually different, and the undulation of the elytra is not quite as strong. On several specimens the denticle behind the tooth on the front femur is larger than usual, causing it to appear bidentate.

BARIS TRICHOCNEMIS, n. sp. Text-fig. 1.

♂. Black, shining.

Rostrum slightly longer than prothorax, base stout; with crowded punctures on sides. Prothorax moderately transverse, sides feebly diminishing in width to beyond the middle; with small and rather distant punctures on disc, becoming larger, but not crowded, on sides. Elytra subcordate, base rather strongly trisinuate, not much and not suddenly wider than prothorax; striae sharply defined but narrow, the inner ones with a few distinct punctures about base, but not elsewhere; interstices impunctate. Under surface with larger punctures than on upper surface, but becoming small on most of abdomen; basal segment with a shallow median depression. Front coxae rather widely separated; femora moderately grooved, the front ones less than the others, each with a small tooth and minute denticles; front tibiae with upper edge slightly incurved, the lower edge with a conspicuous fringe on apical half. Length, 4–5 mm.

♀. Differs in having the rostrum thinner at base, with smaller punctures, abdomen evenly convex, and front tibiae not fringed.

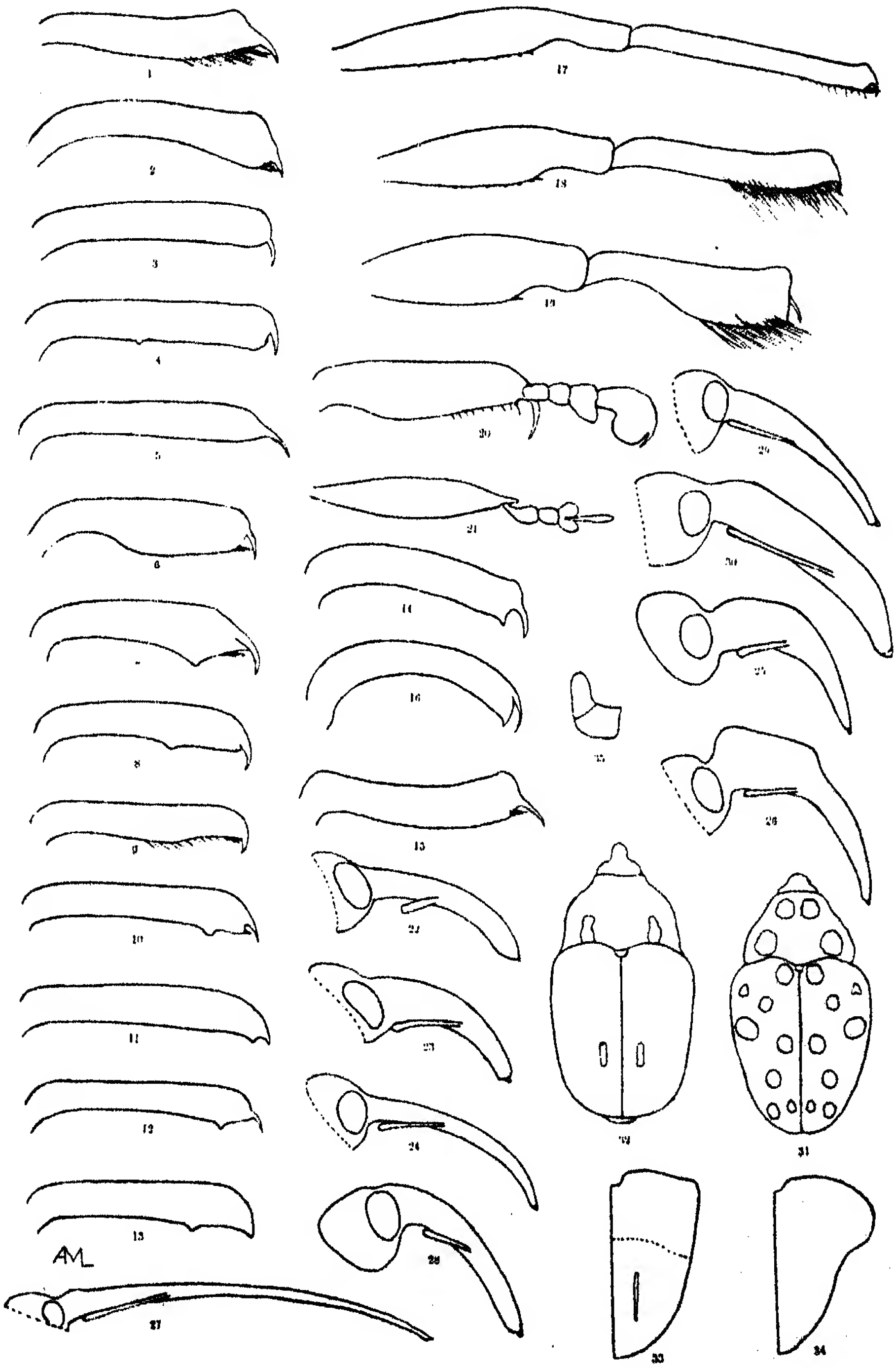
Aru Island (H. Elgner).

Very distinct by the apical fringe of the front tibiae, and the distant coxae. On one specimen of each sex the rostrum is obscurely reddish in front, and on the male the middle tibiae are also obscurely reddish; but on four others no part is reddish.

BARIS LIOSOMA, n. sp. Text-fig. 2.

♂. Black, shining.

Rostrum slightly longer than prothorax; sides with crowded punctures behind antennae. Prothorax moderately transverse; with sparse and minute punctures



on disc, becoming larger, but not crowded, on sides. Elytra oblong-cordate; with sharply defined, narrow striae, containing distinct punctures about base, smaller and disappearing before middle; interstices with a few small punctures about base only. Under surface with fairly large and dense punctures, becoming small on most of abdomen, basal segment with a rather wide median depression. Front coxae rather close together; femora shallowly grooved, each with a rather small acute tooth and denticulate. Length, 4·5–5·0 mm.

♀. Differs in having rostrum slightly longer and thinner, basal segment of abdomen flattened in middle, or very faintly depressed there, with smaller punctures, and legs slightly shorter.

Papua: Mount Lamington and Buna Bay (C. T. McNamara).

In appearance close to the preceding species, but front tibiae of male not fimbriated; the females are distinct by the separation of the front coxae; in appearance also close to *B. atropolita*, but slightly larger and prothoracic punctures even smaller. There are two transverse impressions on the elytra, but they are so faint that the surface could scarcely be regarded as undulating. The denticles of the front femora of the male are somewhat larger than the others, so that on several of them the femora appear bidentate or even tridentate.

BARIS CORDIPENNIS, n. sp.

♂. Black, shining; parts of antennae and of tarsi obscurely reddish.

Rostrum stout, slightly shorter than prothorax; with fairly dense punctures on sides towards base. Prothorax slightly transverse, more convex than usual, sides rather strongly rounded; with small but sharply defined punctures, becoming larger on sides, but nowhere crowded. Elytra cordate; with narrow, sharply defined striae, containing distinct punctures only near base, and even those rather small; interstices impunctate. Under surface with fairly large dense punctures in parts; prosternum with a wide shallow groove almost to base; basal segment of abdomen with a shallow median depression. Front coxae moderately separated, femora acutely dentate. Length, 3·4–3·6 mm.

♀. Differs in having the abdomen strongly convex, with smaller punctures and legs slightly shorter.

Papua: Mount Lamington (C. T. McNamara).

Text-figures 1-35.

1. *Baris trichocnemis* Lea, front tibia.—2. *B. liosoma* Lea, front tibia.—3. *B. edentata* Lea, front tibia.—4. *B. parvidentipes* Lea, front tibia.—5. *B. antennalis* Lea, front tibia.—6. *B. convergens* Lea, front tibia.—7. *B. semipunctata* Lea, front tibia.—8. *B. mesosternalis* Lea, front tibia.—9. *Acythopeus melas* Lea, front tibia.—10. *Melanthia granulipes* Lea, front tibia.—11. *M. regularis* Lea, front tibia.—12. *M. scutellaris* Lea, front tibia.—13. *M. pyritosa* Pasc., front tibia.—14. *M. coxalis* Lea, front tibia.—15. *M. imitator* Lea, front tibia.—16. *M. coxalis* Lea, middle tibia.—17. *Ipsichora longipes* Lea, front femur and tibia.—18. *I. tibialis* Lea, front femur and tibia.—19. *I. piliventris* Lea, front femur and tibia.—20, 21. *Acythopeus unguiculatus* Lea, front tibia and tarsus.—22. *Baris antennalis* Lea, head and rostrum.—23. *B. bialbivitta* Lea, head and rostrum.—24. *B. nemorhina* Lea, head and rostrum.—25. *Acythopeus leucomelas* Lea, head and rostrum.—26. *A. insignis* Lea, head and rostrum.—27. *Myctides filirostris* Lea, head and rostrum.—28. *Melanthia gagatina* Lea, head and rostrum.—29. *M. apina* Lea, head and rostrum.—30. *Ipsichora piliventris* Lea, head and rostrum.—31. *Baris multimaculata* Lea, markings of upper surface.—32. *Acythopeus leucomelas* Lea, markings of upper surface.—33. *Aulacobaris pictipennis* Lea, elytron.—34. *Degis trigonopterus* Pasc., elytron.—35. *D. trigonopterus*, front coxa.

With the narrow sharply defined striae of some of the preceding species, but elytra not at all undulated, prothorax more convex, and rostrum decidedly shorter and stouter. Although the elytra are trisinuate at the base, when viewed from behind only the median sinus is evident, and the heart-shaped appearance is conspicuous. The femoral teeth are small, but acute and well defined, on the front pair they are nearer the base than is usual, and there are two on those of the type; on the female there are two on the left femur, but only one on the right.

BARIS TENUICORNIS, n. sp.

♀. Black, shining; parts of rostrum, of antennae, and of tarsi obscurely diluted with red.

Rostrum comparatively thin and slightly longer than prothorax. Antennae thinner than usual. Prothorax moderately transverse, strongly convex, sides strongly rounded; with numerous, but not crowded, and rather small, deep punctures becoming larger, but not dense, on sides. Elytra cordate; with narrow, deep striae, containing punctures that are visible from but few directions; interstices with a few small punctures about base and apex. Under surface with larger and more numerous punctures than on prothorax, but becoming sparse and small on most of abdomen. Prosternum with a shallow groove from apex to base, but with bounding carinae only in front of coxae; abdomen rather strongly convex. Front coxae rather widely separated, femora slightly but acutely dentate, and minutely denticulate. Length, 4·5 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

A strongly convex species, with the heart-shaped elytra and general outlines of the preceding species, but somewhat larger, rostrum decidedly longer and thinner, prosternal groove shallower and femoral teeth in the usual positions.

BARIS EDENTATA, n. sp. Text-fig. 3.

♂. Black, shining. Sterna and base of abdomen with numerous white setae.

Rostrum the length of prothorax; with crowded but not very large punctures on sides of basal half. Prothorax scarcely wider than long, sides almost evenly diminishing in width from base to apex; upper surface with small and sparse but rather sharp punctures, becoming larger and denser on sides. Elytra with sides rather rapidly diminishing behind shoulders; with sharply defined but fine striae, containing distinct punctures that vanish behind the middle; interstices impunctate even at base. Under surface with crowded punctures somewhat as on sides of prothorax, but becoming sparse and small on most of abdomen, basal segment with a shallow median depression, apical one with a moderately large, round fovea. Front coxae fairly close together, femora shallowly grooved and edentate. Length, 3·5 mm.

Papua: Bisiatabu (Rev. W. N. Lock). Unique.

In general appearance fairly close to *B. atropolita*, but elytra more rapidly narrowed from near the base, and femora edentate. The prosternum has a narrow groove, but it is partly concealed by the clothing, even after the head has been removed.

BARIS PARVIDENTIPES, n. sp. Text-fig. 4.

♂. Black, shining; parts of antennae obscurely reddish. Sterna, base of abdomen, under parts of legs and upper surface of middle and of hind femora, with stout white setae or scales.

Rostrum at its junction with head with a shallow transverse impression, rather strongly curved, slightly longer than prothorax; with crowded and fairly coarse punctures on basal sides. Prothorax almost as long as the basal width, a shallow transverse impression on the scutellar lobe; with sparse and minute punctures, becoming moderately large and numerous, but not crowded, on sides. Elytra cordate, rapidly narrowed behind the shoulders; with fine striae, the sutural and marginal ones with a few distinct punctures towards base, but not elsewhere; interstices impunctate. Sterna and base of abdomen with dense, partly concealed punctures, small on rest of abdomen; basal segment with a fairly large depression from base to apex. Front coxae moderately separated, femora grooved and edentate, front tibiae with an obtuse median tooth or granule on lower surface. Length, 3·5 mm.

♀. Differs in having abdomen evenly convex and legs slightly shorter, with the front tibiae unarmed.

Papua: Mount Lamington (C. T. McNamara).

Distinct by the front tibiae of the male. The white clothing is fairly dense on the metasternal episterna, and on the upper surface of some of the femora, but is very sparse on the abdomen.

Baris obscuripes, n. sp.

♀. Black, shining.

Rostrum moderately stout, slightly shorter than prothorax; with crowded and not very large punctures on sides behind antennae. Prothorax slightly transverse, a feeble impression across scutellar lobe; with sparse and minute punctures, becoming larger on sides. Elytra cordate; striae fine, but containing distinct punctures, becoming smaller posteriorly; interstices impunctate. Under surface with sharply defined punctures of moderate size, small on most of abdomen, which is evenly convex; pygidium just perceptible. Front coxae moderately separated, femora grooved and edentate. Length, 3·5 mm.

New Guinea: Wareo (Rev. L. Wagner). Unique.

In appearance fairly close to the preceding species, but without white clothing, and the striae with more numerous punctures; it is also clôse to *B. edentata*, but is slightly more robust, and even the under parts are glabrous. In its rather wide rostrum, with series of punctures on elytra it approaches *Metanthia*, in the almost complete concealment of the pygidium *Gymnobaris*. The prothoracic punctures, although minute, are sharply defined.

Baris antennalis, n. sp. Text-figs. 5, 22.

♂. Black, shining; parts of legs and of rostrum obscurely diluted with red, antennae reddish.

Rostrum almost the length of prothorax, of almost equal thickness throughout, base not transversely impressed; with fairly dense punctures on sides behind antennae. Antennae inserted slightly nearer base than apex of rostrum. Prothorax slightly longer than wide, sides evenly decreasing in width from base to apex; with sparse and minute punctures, becoming larger, but still sparse and small, on sides. Elytra elongate-cordate; with sharp striae containing distinct punctures on basal third (less behind shoulders than towards suture), very fine or impunctate elsewhere; interstices impunctate. Metasternum with rather large and dense punctures. Abdomen with sparse and small punctures, but becoming

dense on apical segment, basal one shallowly impressed along middle. Legs rather long and thin, femora minutely but acutely dentate. Length, 2·8 mm.

♀. Differs in having rostrum thinner and slightly longer, abdomen rather strongly and evenly convex, and femoral teeth even smaller.

Papua: Mount Lamington (C. T. McNamara).

A narrow species, with antennae inserted slightly nearer the base than apex of rostrum; on all the other species here named, unless otherwise noted, they are inserted from one-third to two-fifths from the apex. The striae towards base of elytra are about one-third of the width of the interstices, but (except the sutural and marginal ones) they almost vanish posteriorly. From most directions the femoral teeth are invisible.

Baris megalops, n. sp.

♀. Black, shining; antennae reddish, tarsi obscurely reddish.

Eyes large and almost touching. Rostrum about the length of prothorax, upper surface ridged towards base, not transversely impressed at junction with head; near eyes with rather dense punctures. Prothorax almost as long as the basal width; upper surface with sparse and very minute punctures, the sides with some sharply defined ones, but sparse and not very large. Elytra short and cordate; with distinct striae containing punctures about basal third, the sutural and marginal striae continued beyond middle, elsewhere neither striate nor punctate. Prosternum with a shallow groove in front. Metasternum with crowded punctures. Abdomen convex and almost impunctate. Legs rather long and thin, femora dentate. Length, 3 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

The elytra have a few striae containing distinct punctures about the base, somewhat as on the preceding species, but most of the surface is without either striae or punctures. The front femora are scarcely visibly dentate, each of the others has two small but acute teeth and some smaller ones.

Baris castaneicornis, n. sp.

♀. Black, shining; legs obscurely diluted with red, antennae pale castaneous.

Rostrum the length of prothorax, slightly dilated to base, not transversely impressed at junction with head; with dense and small punctures on sides, minute elsewhere. Prothorax moderately transverse, sides rather strongly rounded; with scarcely visible punctures, even on sides. Elytra short and cordate, with faint striae, containing small punctures in places. Metasternum with distinct punctures towards sides only. Abdomen convex and impunctate. Legs long, femora acutely dentate, tibiae with upper edge very feebly incurved. Length, 3 mm.

New Guinea: Wareo (Rev. L. Wagner). Unique.

In appearance close to the preceding species, but eyes not close together, metasternum impunctate, except towards sides, and femora sharply unidentate. The sutural and marginal striae are fairly distinct, and punctures in striae are faintly traceable elsewhere.

Baris punctimedia, n. sp.

♀. Black, shining.

Rostrum the length of prothorax, with a rather wide but shallow impression at its junction with head; with crowded punctures on sides. Prothorax almost

as long as wide, rather strongly convex; with punctures of moderate size and not very close together on upper surface, becoming crowded on sides. Elytra very little wider than prothorax, parallel-sided to about middle; with narrow but sharply defined striae, containing a few small punctures towards base; interstices impunctate. Metasternum with crowded punctures as on sides of prothorax; abdomen with much smaller and sparser ones. Legs moderately long, femora slightly grooved and edentate. Length, 2·5 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

A small species, fairly distinct by the wide depression at base of rostrum, and sharply defined and rather distant punctures of pronotum.

BARIS TENUIPES, n. sp.

♀. Black, shining; tip of rostrum and tarsi obscurely reddish, antennae paler.

Eyes large and almost touching. Rostrum slightly longer than prothorax, somewhat narrowed to apex, not transversely impressed at base; sides with crowded punctures behind antennae, minute elsewhere. Prothorax slightly longer than wide, sides decreasing in width from base; upper surface impunctate, the sides with a few small but fairly sharp punctures. Elytra cordate; striae sharply defined throughout, and containing some fairly distinct punctures on basal half, ill-defined or absent elsewhere; interstices impunctate. Metasternum with crowded punctures. Abdomen evenly convex, with a few well-defined punctures about base, sparse and small elsewhere. Legs long and thin, femora minutely dentate. Length, 2·3 mm.

New Guinea: Hudewa (Rev. L. Wagner). Unique.

The eyes are large and close together, much as on *B. megalops*, but it differs from that species in the regular elytral striae, thinner rostrum and different dentition of femora.

BARIS FOVEATA, n. sp.

Black, shining; tip of rostrum and parts of antennae obscurely reddish.

Rostrum not very stout, slightly shorter than prothorax, not transversely impressed at base; with crowded punctures on sides behind antennae. Prothorax slightly longer than wide, sides regularly decreasing in width to apex; upper surface impunctate; sides with sharply defined and fairly numerous punctures. Elytra elongate-cordate; striae sharply defined, except near sides, but traceable there, and almost impunctate; interstices impunctate. Metasternum with crowded punctures. Abdomen with a few distinct punctures about base, but small elsewhere, basal segment feebly convex in middle, the apical segment foveate. Legs moderately long, femora edentate, tibiae with upper edge faintly incurved to middle. Length, 2·2 mm.

Queensland (Dr. W. Horn, from Franklin Müller). Unique.

In appearance close to the preceding species, and with similar elytral striae and prothoracic punctures, but differs in having the eyes well separated, legs slightly shorter and femora edentate. The sex of the type is doubtful, as although the basal segment of abdomen is not concave along middle, as on most males, the apical one is foveate.

BARIS MONOBIA, n. sp.

Black, shining.

Rostrum the length of prothorax, arched at base; sides behind antennae with crowded but rather small punctures. Prothorax slightly transverse; with

sparse and small punctures on upper surface, becoming larger and crowded on sides. Elytra subcordate; with sharply defined, fine striae, each with a series of small punctures, some of which do not extend much beyond the middle; interstices impunctate. Metasternum with numerous but scarcely crowded punctures of moderate size, becoming sparse and small on abdomen. Prosternum feebly depressed along middle. Legs moderately long, front coxae widely separated, femora slightly grooved and acutely dentate. Length, 2·5 mm.

Torres Straits: Cornwallis Island (C. T. McNamara). Unique.

Close to the preceding species, but rostrum longer and depressed at its junction with head. It is fairly close to *B. vulnerata* in appearance, but on that species the head is conspicuously foveate in front. There is a faint depression at the apex of the basal segment of abdomen, but the type is probably a female.

Baris convergens, n. sp. Text-fig. 6.

♂. Black, somewhat shining.

Rostrum the length of prothorax; with crowded punctures, becoming rather small in front. Prothorax moderately transverse; with dense punctures of moderate size. Elytra cordate, with sharp striae containing deep-set inconspicuous punctures; interstices with fairly large punctures about base, smaller posteriorly, but distinct throughout. Under surface with crowded punctures, smaller on abdomen than elsewhere, the latter with a feeble depression on two basal segments. Femora slightly dentate. Length, 3 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

Close to *B. porosa* from Queensland (and like that species it should possibly be referred to *Acythopeus*), but the elytra are more shining and with smaller punctures. It is about the size of *B. sororia*, but is slightly more convex, and there is no clothing on the scutellar lobe.

Baris semipunctata, n. sp. Text-fig. 7.

♂. Black, shining.

Rostrum the length of prothorax, upper surface obtusely ridged near base; sides with crowded punctures behind antennae. Prothorax moderately transverse, sides almost evenly decreasing in width to apex; with sharply defined punctures of moderate size, becoming crowded on sides. Elytra cordate; with series of punctures in regular striae, the punctures rather large at base and decreasing in size to apex; interstices impunctate. Metasternum and base of abdomen with crowded and deep punctures, basal segment feebly depressed in middle. Front coxae moderately separated, femora edentate, lower surface of front tibiae with an obtuse swelling at apical fourth. Length, 2 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

In size and with outlines much as *B. angophorae* or small *B. sororia*, but prothoracic punctures not crowded on disc (although quite numerous), and elytral interstices impunctate; the punctures in the striae are almost as wide as the interstices at the base, but rapidly decrease in size. The eyes are fairly close together, although not as close as on *B. megalops* and *tenuipes*. The slight swelling of the front tibiae could be easily overlooked; it is considerably nearer the apex than on *B. parvidentipes*.

Baris vigilans, n. sp.

♀. Black, shining; antennae and tarsi obscurely diluted with red, abdomen reddish.

Eyes large and almost touching. Rostrum not very stout, slightly shorter than prothorax, not transversely impressed at base. Prothorax slightly wider than head, rapidly diminishing in width from base to apex; upper surface with sparse and minute punctures, becoming larger, but not crowded, on sides. Elytra cordate; with rows of distinct punctures in feeble striae, the punctures becoming feeble posteriorly and on the sides, but the striae more distinct there. Metasternum with sharply defined punctures of moderate size and not dense. Abdomen evenly convex, with sparse and minute punctures. Legs not very long, femora feebly grooved and edentate, upper edge of tibiae gently arched, more strongly at base. Length, 2 mm.

New Guinea: Finsch Haven (Rev. L. Wagner). Unique.

The eyes are much as on *B. megalops* and *tenuipes*, from each of which the species differs in the punctures of elytra, shorter legs, and edentate femora. The outlines of the head and prothorax, from above, are almost equilaterally triangular. The abdomen of the type is distinctly reddish, but this may be due to immaturity.

BARIS MESOSTERNALIS, n. sp. Text-fig. 8.

♂. Black, shining; antennae obscurely diluted with red. A narrow white vitta on each elytron towards apex, prosternum, sides of metasternum, tip of abdomen, sides of rostrum and legs (including upper surface of femora), with stout white setae or scales.

Rostrum the length of prothorax; sides with moderately dense punctures, partly concealed by clothing. Prothorax almost as long as wide, rather strongly convex; with very minute punctures, even on sides. Elytra subcordate, outlines continuous with those of prothorax; with fine, regular, and almost impunctate striae; interstices impunctate. Metasternum with punctures of moderate size and not very dense; side pieces of mesosternum almost impunctate. Abdomen with crowded punctures on apical segment, and moderately dense towards base, elsewhere sparse and minute; basal segment with a wide depression from base to apex. Legs moderately long, femora feebly grooved, dentate and minutely denticulate, front tibiae slightly armed on under surface, at about one-third from apex. Length, 4·0–4·5 mm.

♀. Differs in being slightly larger, rostrum thinner, slightly longer than prothorax, abdomen more convex, punctures on basal segment sparser and smaller, and front tibiae simple.

New Guinea: Finsch Haven (Rev. L. Wagner); Papua: Mount Lamington (C. T. McNamara).

This and the next species are very distinct by the almost complete absence of punctures from the side pieces of the mesosternum, except for a few minute submarginal ones. The elytra from behind appear truly cordate, as the sublateral sinuations of the base disappear when so viewed; from some directions the striae appear to have a few minute punctures, but they are invisible from most directions. The vitta on each elytron of two males (which were trapped by sticky seeds of a *Pisonia*) is not confined to the fifth interstice, but is partly on the fourth as well, but the only female is entirely without vittae, although quite evidently it belongs to the same species. The projection on the front tibiae of the male is somewhat as on *B. semipunctata*, but that species is much smaller, with normal punctures on the mesosternum.

BARIS LAEVISSIMA, n. sp.

Black, shining.

Rostrum about the length of prothorax; with strong crowded punctures on sides behind antennae. Prothorax moderately transverse; with sparse and minute punctures, no larger on sides than elsewhere. Elytra subcordate, outlines continuous with those of prothorax; with fine, sharply defined striae, containing minute punctures, but the first three on each side of the suture with fairly distinct ones towards base; interstices impunctate. Under surface with sparse and minute punctures except for a few about coxae, and on side pieces of metasternum. Prosternum with a wide shallow depression in front. Front coxae widely separated, femora edentate, the middle and hind ones distinctly grooved. Length, 4·0–4·5 mm.

New Guinea: Wareo (Rev. L. Wagner); Papua: Mount Lamington (C. T. McNamara).

In appearance close to the preceding species, and with similar mesosternum, but slightly more robust, sparser punctures on under surface (notably on the metasternum and apex of abdomen), femora edentate and more distinctly grooved. The type is possibly a male, as the basal segment of its abdomen is flat or feebly depressed in the middle, the other specimens (two) have the abdomen more convex, but as there are no sexual differences in the front tibiae, all three are probably females.

BARIS SIMPLICIPENNIS, n. sp.

♂. Black, shining.

Rostrum rather thin, slightly longer than prothorax; punctures small and not crowded, even near base. Prothorax slightly transverse, strongly narrowed near apex; with sparse and minute punctures, even on sides. Elytra cordate; with a fairly distinct subsutural row of punctures on basal half, and shorter rows of smaller punctures near base. Under surface with sparse but sharply defined punctures. Basal segment of abdomen with a shallow depression in middle, clothed with setae slightly longer than on legs. Legs rather long, coxae widely separated, the front ones more than the others, femora with a small but acute tooth, followed by small denticles. Length, 3 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

The prosternum is shallowly depressed along the middle, but could scarcely be regarded as grooved, and the front coxae are too widely separated for the species to be referred to *Metanthia*, to which, from the upper surface, it would appear to belong. In general appearance it is fairly close to *B. mesosternalis* and *laevissima*, from each of which it is distinct by the sharply defined, although not abundant punctures on side pieces of the mesosternum, and abdominal clothing, which, however, is probably confined to the male; the former has fairly distinct striae and bivittate elytra, the latter has edentate femora. Faint remnants of striae are traceable only near the suture and sides, and the seriate punctures, except that the subsutural row is fairly distinct, are also very feeble.

BARIS BIALBIVITTA, n. sp. Text-fig. 23.

♂. Black, shining; antennae reddish, tarsi darker. Each elytron with a long thin white vitta on the fifth interstice beyond the middle, and a few setae at the apex; legs with distinct white setae, and a few on parts of sterna.

Rostrum slightly longer than prothorax; with crowded and fairly strong punctures on sides behind antennae. Prothorax with fairly dense but not crowded punctures of moderate size, becoming slightly larger on sides. Elytra subcordate; with sharply defined striae containing distinct but not large punctures; interstices with very minute punctures. Metasternum with dense and fairly large punctures, becoming smaller and sparser on the following segment (which has a wide shallow depression), and still smaller and sparser on rest of abdomen. Front coxae moderately separated, femora rather stout, feebly grooved and feebly dentate, tibiae straight. Length, 4 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

The elytra are conspicuously bivittate. The prosternum has a narrow groove bounded by a fine carina on each side, but to see it clearly the head must be removed.

BARIS INUSITATA, n. sp.

♀. Black, shining; antennae and tarsi obscurely diluted with red. Each elytron with a narrow white vitta on the fifth interstice, at about one-fifth from the apex.

Rostrum slightly longer than prothorax; with crowded punctures on sides behind antennae. Prothorax slightly transverse; with dense and fairly large punctures on middle and sides, a fairly wide space towards each side polished and with sparse and very minute punctures. Elytra subcordate; with sharply defined striae containing small, deep-set punctures; interstices impunctate, except the marginal one at apex. Prosternum with a slight pectoral canal. Metasternum with crowded punctures in middle and on episterna, the interspaces highly polished and impunctate. Abdomen gently convex, the basal segment and part of the second with punctures about as large as on metasternum, but much sparser, elsewhere with sparse and minute ones. Front coxae moderately separated, femora feebly grooved and acutely but not strongly dentate, upper edge of tibiae gently incurved in middle. Length, 4·5 mm.

New Guinea: Manumbo (Madang district). Unique.

In appearance fairly close to the preceding species, but with remarkable prothoracic and metasternal punctures, setae of legs much smaller, femora more strongly dentate, and upper edge of tibiae different.

BARIS STICTOPTERA, n. sp.

♀. Black; most parts with a bluish gloss. Elytra with four white spots or two incomplete fasciae, sides of metasternum with fairly dense white setae, the legs with a small white seta in each puncture.

Rostrum rather thin, slightly longer than prothorax; with crowded but not very large punctures on sides behind antennae, which are inserted just perceptibly in advance of the middle. Prothorax scarcely wider than long, sides almost parallel to near apex; with dense but not crowded punctures of moderate size. Elytra thin, parallel-sided to beyond the middle; with sharp striae containing small, deep-set punctures; interstices with small sharp punctures, not confined to a single row on each. Under surface with crowded punctures about as large as on pronotum, but becoming sparser and smaller on abdomen, basal segments flattened in middle. Legs rather long, femora edentate. Length, 4 mm.

New Guinea: Caprivizipfel (Dr. W. Horn, from — v. Bennigsen). Unique.

A rather narrow, bluish species, with distinct elytral markings, which consist of a fairly large white spot on each side of the base close to the scutellum, and another at the apical third, from the second interstice to the sixth.

BARIS BIMACULIBASIS, n. sp.

♂. Black, shining. Each elytron with a conspicuous white spot on the third interstice at base, under surface in places with fairly distinct whitish setae, becoming minute on legs.

Rostrum rather stout, the length of prothorax; with crowded punctures on sides behind antennae. Prothorax slightly transverse, sides rather strongly rounded; with numerous but not crowded punctures of moderate size, becoming larger on sides. Elytra subcordate; with sharply defined striae containing distinct punctures on basal half, becoming fairly large close to base; interstices impunctate. Metasternum with crowded punctures, sparser on basal segment of abdomen (which is feebly depressed along middle), and still smaller and sparser elsewhere. Femora feebly grooved and edentate. Length, 2 mm.

♀. Differs in having abdomen evenly convex.

Papua: Mount Lamington (C. T. McNamara).

A small species, with two white spots at the base of the elytra.

BARIS EURYSTERNA, n. sp.

♂. Black, shining. Third interstice on each elytron at base, under surface and legs with white scales.

Rostrum the length of prothorax; with crowded and rather coarse punctures on sides behind antennae, smaller but still dense elsewhere. Prothorax very little wider than long, rather strongly convex; with dense but not crowded, sharply defined punctures of moderate size. Elytra oblong-cordate; with sharply defined striae containing a few deep-set punctures; interstices with a few small punctures at base and about apex. Under surface with dense punctures, becoming smaller and sparser on parts of abdomen, two basal segments with a wide shallow depression. Front coxae widely separated, femora moderately grooved and edentate, front tibiae fimbriated on apical half of lower surface. Length, 4·5–5·2 mm.

♀. Differs in having the rostrum slightly longer and thinner, abdomen evenly convex, front coxae less widely separated and front tibiae not fimbriated.

Papua: Mount Lamington (C. T. McNamara).

The front coxae are more widely separated than is usual in the genus. The basal clothing of the elytra forms two feeble spots on each of three specimens under examination, but could be easily abraded, on the under surface and legs there is a single scale in each puncture, but the metasternal episterna and upper parts of the femora are rather densely clothed; there are also a few scales at the basal sides of rostrum.

BARIS MULTIMACULATA, n. sp. Text-fig. 31.

♂. Black, shining. With numerous spots of snowy-white scales.

Rostrum slightly longer than prothorax; with crowded punctures on sides behind antennae, which are inserted at apical fourth, and smaller, but still numerous, elsewhere. Prothorax not much wider than long, sides evenly diminishing in width to apex; with sharply defined but not very large or dense punctures, becoming crowded on sides. Elytra cordate; with sharply defined

striae containing punctures of moderate size towards base, but small elsewhere; about five of the lateral interstices with fairly distinct punctures, absent elsewhere. Basal segment of abdomen depressed along middle. Femora moderately grooved and edentate. Length, 3 mm.

Malay Peninsula: Kuala Lumpur (A. M. Lea). Unique.

The snowy spots on the upper surface are almost evenly distributed; there are four on the pronotum, sixteen on the elytra, and one on the upper surface of each femur: twenty-six in all; in addition there are some white setae scattered about on the under surface and legs and fairly dense on parts of the metasternum.

BARIS NEMORHINA, n. sp. Text-fig. 24.

♂. Black, shining; parts of antennae and of legs somewhat reddish. With a small seta in each puncture.

Rostrum thin, slightly longer than prothorax. Antennae inserted in middle of sides of rostrum. Prothorax slightly wider than long, disc but feebly convex; with numerous but not crowded punctures of moderate size on disc, and leaving an impunctate median line, the sides with crowded punctures. Elytra subcordate; with comparatively wide striae containing deep-set punctures; the interstices each with a row of small punctures. Sterna with dense punctures, becoming smaller and sparser on abdomen, basal segment with a shallow depression along middle. Femora feebly grooved and edentate. Length, 2·7 mm.

Fiji (Dr. W. Horn, from — Kraatz). Unique.

In shape approaching *B. angophorae* and *sororia*, from Australia. The setae scarcely differ in length on the body and legs, on the elytra they form a row on each interstice. Seen from above the rostrum appears much thinner than the femora.

BARIS BASIPENNIS, n. sp.

♀. Dark brown and somewhat shining. With a few setae scattered about.

Rostrum almost the length of prothorax; with fairly coarse punctures on sides behind antennae. Prothorax moderately transverse; with crowded punctures, in places becoming transversely confluent. Elytra subcordate; with sharply defined striae containing deep-set punctures; interstices each with a row of punctures. Sterna with crowded punctures, becoming smaller and sparser on abdomen, especially on the intermediate segments. Femora feebly grooved and edentate. Length, 2 mm.

Fiji: Viti Levu (A. M. Lea). Unique.

A small species, with rather coarse punctures on prothorax. There is a wide shallow depression on the elytra at the basal third, causing the base, from the sides, to appear slightly gibbous.

BARIS VITIENSIS, n. sp.

♀. Blackish and shining, rostrum, antennae, and legs obscurely diluted with red. Elytra with a few small white spots, under parts sparsely clothed.

Eyes rather large. Rostrum moderately thin, the length of prothorax, not depressed at its junction with head. Prothorax moderately transverse; with sparse and small punctures on upper surface, becoming larger and crowded on sides. Elytra cordate; with sharply defined striae, containing deep-set punctures; interstices with fairly distinct ones, but almost impunctate in middle. Sterna

with dense punctures, smaller and sparser on abdomen. Femora feebly grooved and edentate. Length, 2 mm.

Fiji: Viti Levu (A. M. Lea). Unique.

The outlines are somewhat as on *B. angophorae* and *sororia*, but the punctures and clothing are very different.

BARIS POROSA Lea.

Mr. G. F. Hill took six specimens of this species, at Darwin, on *Careya australis*.

BARIS SORORIA Lea.

This species occurs in Papua (Port Moresby) and Aru, as well as in Queensland.

ZENA.

Pasc., *Ann. Mus. Civ. Gen.*, 1885, p. 295.

ZENA VITTIPENNIS, n. sp.

♂. Black, shining. With rather dense clothing in parts, the elytra vittate.

Rostrum the length of prothorax; with crowded, partly concealed punctures on sides behind antennae. Prothorax moderately transverse; with sharply defined but rather small and not crowded punctures on disc, becoming larger and denser on sides, and leaving a narrow impunctate median line. Elytra oblong-cordate; with acute striae containing deep-set punctures, larger about base than elsewhere; interstices with fairly large but partly concealed punctures about base and sides, smaller elsewhere. Two basal segments of abdomen shallowly depressed along middle. Femora edentate. Length, 4-5 mm.

♀. Differs in having the rostrum slightly longer than the prothorax, and abdomen evenly convex.

Papua: Mount Lamington (C. T. McNamara); New Guinea: Finsch Haven (Rev. L. Wagner), Manumbo (Madang district).

Allied to *Z. cynethioides*, but smaller; on two specimens of the type series of that species there is a white vitta on the fourth interstice of each elytron, adjacent to a longer one on the fifth, and with another small one at the base of the third. On eight specimens of the present one the fourth interstice is non-vittate. Each side of the prothorax is rather densely clothed, but has a fairly large glabrous space, partly visible from above; on each elytron there are scattered scales on the sides and apex, and two small vittae on the third interstice, one at the base, the other at the middle, adjacent to the latter on the fifth interstice there is a longer vitta, occupying rather more than the median third, on the under surface and legs the clothing is dense, especially on the metasternal episterna; there are also a few scales on the sides of the rostrum. On three specimens parts of the elytra and of the legs are somewhat reddish.

ZENA MEGAPHOLA, n. sp.

♀. Piceous-brown and subopaque. With conspicuous spots of large, stramineous scales.

Rostrum slightly longer than prothorax, gibbous at base; with crowded and rather coarse punctures on sides behind antennae (these inserted slightly nearer base than apex), small and sparse in front. Prothorax slightly transverse; with

dense punctures of moderate size. Elytra subcordate, not much wider than prothorax; punctate-striate, the interstices each with a series of fairly large punctures, becoming crowded at base. Metasternum with punctures as on pronotum, small and sparse on abdomen, but dense on apical segment. Femora with a row of granules on each side of a shallow groove. Length, 4 mm.

Malay Peninsula: Kuala Lumpur (A. M. Lea). Unique.

Very distinctively clothed with large, stramineous scales, which form a vitta on each side of the base of the prothorax, and a small spot (invisible from above) on each side in front; on each elytron they form two vittae on the fourth interstice, one at the base, the other in the middle, and a small spot at the apex; on the under surface the scales are fairly dense between the front coxae, form a curved row from the hind to middle coxae, and between the latter, are dense on the metasternal episterna, and form six spots on the abdomen: four on the second segment, and one on each side of the first.

SOLENOBARIS.

Lea, *Trans. Roy. Soc. S. Aust.*, 1906, p. 102.

This genus was known only from Queensland, but several species are now before me from New Guinea and Fiji; its species all have the prosternum sharply grooved (as in many Cryptorhynchinae). The head usually has a small interocular fovea or large puncture, but is without the transverse depression at its junction with the rostrum that so many species of *Baris* have; the elytra are usually seriate-punctate, and usually without continuous striae, or only near suture and sides.

SOLENOBARIS INSIGNIROSTRIS, n. sp.

♂. Black, shining.

Head with a small interocular fovea. Rostrum slightly curved, about one-fourth longer than prothorax; with dense punctures, often confluent behind antennae; apical half ridged along middle. Antennae inserted almost in exact middle of sides of rostrum, scape about half the length of funicle and club combined. Prothorax slightly transverse, upper surface with sparse and minute punctures, becoming slightly larger close to base, and distinctly larger on sides near legs. Elytra cordate; almost non-striate, with regular series of punctures of moderate size about base, but rapidly diminishing posteriorly; interstices with sparse and minute punctures. Metasternum with crowded punctures, becoming sparser on basal segment of abdomen, and still sparser and smaller on the others; basal segment with a wide depression along middle. Legs moderately long, femora feebly grooved, slightly but acutely dentate, and with a few minute denticles. Length, 4·5–5·0 mm.

♀. Differs in having slightly smaller eyes, thinner rostrum, and abdomen evenly convex.

New Guinea: Wareo (Rev. L. Wagner).

The largest known species of the genus. The ridge on the apical half of the rostrum is quite acute, each side of it being obliquely flattened, so that the rostrum there, in transverse section, is equilaterally triangular.

SOLENOBARIS DENTICULATA, n. sp.

♂. Black, moderately shining.

Rostrum slightly longer than prothorax, slightly ridged along middle; with crowded but not large punctures behind antennae, and at base of upper surface. Antennae inserted slightly nearer base than apex of rostrum. Prothorax moderately transverse, rather strongly convex; with dense but not crowded and rather small but sharply defined punctures. Elytra with regular rows of punctures of moderate size, becoming much smaller posteriorly; the striae very feeble. Metasternum with crowded punctures, slightly larger than on pronotum. Basal segment of abdomen widely depressed along middle, with punctures about as large as on metasternum, but sparser, apical segment with crowded punctures, the third and fourth each with a single row across middle. Femora each with an acute tooth, followed by a row of denticles. Length, 3·5–4·0 mm.

♀. Differs in having slightly smaller eyes, longer rostrum, abdomen evenly convex and with more crowded punctures on two basal segments.

Aru Islands (H. Elgner).

Smaller than the preceding species, rostrum less acutely ridged, pectoral canal deeper, and femora with more numerous denticles.

SOLENOBARIS ORTHORRHINA, n. sp.

♀. Black, shining.

Rostrum about one-fourth longer than prothorax, almost straight, upper surface flattened near apex; with dense punctures on sides behind antennae (these inserted almost in exact middle of sides). Prothorax slightly transverse; with sparse and minute punctures on upper surface, becoming numerous and moderately large on sides. Elytra subcordate; with rows of fairly large punctures about base, rapidly becoming smaller and vanishing before the middle, striation very faint. Metasternum and base of abdomen with crowded punctures, the abdomen evenly convex. Femora each with a small acute tooth and small denticles. Length, 2·4–2·6 mm.

Papua: Mount Lamington (C. T. McNamara).

In general appearance close to *S. decipiens* (from Queensland), but narrower, rostrum longer and straighter, and femora acutely dentate.

SOLENOBARIS HAMATA, n. sp.

♂. Black, shining; antennae and tarsi obscurely reddish.

Rostrum rather wide, parallel-sided, strongly curved and no longer than prothorax; with dense punctures on sides towards base, small and sparse elsewhere. Antennae inserted slightly nearer apex than base of rostrum. Prothorax with scarcely visible punctures, even on sides. Elytra rather short, with basal incurvature only about scutellum; nonstriate, but with rows of small punctures, vanishing posteriorly. Metasternum with some coarse punctures between coxae, its episterna, as also those of the mesosternum, each with a row of strong punctures, curved at the end like a hook. Abdomen shallowly depressed along middle of basal segment, with a few distinct punctures about base, apical segment with small but numerous ones. Femora grooved and edentate. Length, 3·5 mm.

New Guinea: Hudewa (Rev. L. Wagner). Unique.

The front femora are moderately grooved, but the groove on each of the others is rather wide, the rostrum is also wider and shorter than usual, but as the pectoral canal is wide, deep and sharply defined, it does not appear desirable to propose a new genus for the species. In some respects it approaches *Metanthia*.

A specimen from Mount Lamington (C. T. McNamara) possibly belongs to this species, but has the rostrum distinctly longer, thinner, and less curved; it is evidently also a male, as the metasternum and abdomen are identical with the type; the punctures on the mesosternal episterna are sparse but do not form a hook.

SOLENOBARIS PARVIPUNCTATA, n. sp.

♂. Black, shining; antennae reddish.

Rostrum not very stout, the length of prothorax; with numerous but not crowded punctures behind antennae (which are inserted nearer apex than base). Prothorax slightly transverse, sides rapidly decreasing in width to apex; with sparse and minute punctures, even on sides. Elytra cordate, outlines continuous with those of prothorax, sides from near base more rapidly diminishing in width to apex than usual; with short rows of small punctures, two rows near suture more distinct and longer than the others. Metasternum with numerous distinct punctures. Basal segment of abdomen with a fairly deep median depression, continued on to second, with a few small punctures about base, the apical segment rather densely punctate. Legs rather long, femora grooved and edentate. Length, 3·5 mm.

Queensland: Dunk Island (H. Hacker). Type (unique) in Queensland Museum.

On removing the head the pectoral canal is seen to have well defined walls between the front coxae, but it is rather shallower in front than is usual in the genus. From the preceding species it differs in being slightly narrower, rostrum distinctly longer, basal segment of abdomen conspicuously depressed along middle, and femora less widely grooved.

The elytra are nonstriate, and the series of punctures are so small and short, that most parts are practically impunctate.

SOLENOBARIS INERMIS, n. sp.

♂. Black, shining; parts of antennae reddish. Head between eyes, base of rostrum, and under surface with whitish or yellowish clothing.

Head scarcely impressed between eyes. Rostrum rather wide, moderately curved, the length of prothorax. Antennae inserted slightly nearer apex than base of rostrum. Prothorax slightly transverse, sides slightly rounded and decreasing in width from base to apex; with sharply defined but not very large or dense punctures, becoming slightly larger on sides. Elytra subcordate; with rows of fairly large punctures in feeble striae about base, smaller but in more distinct striae posteriorly. Metasternum with crowded punctures, becoming smaller on most of abdomen, basal segment widely depressed along middle. Legs rather thin, femora edentate. Length, 2 mm.

♀. Differs in having slightly thinner rostrum, shorter legs and abdomen evenly convex.

Papua: Mount Lamington (C. T. McNamara).

Smaller and somewhat narrower than *S. edentata*, and with somewhat thinner legs. There are fairly distinct striae on the elytra, but they are feeble where the seriate punctures are largest. One male has the abdomen partly reddish.

SOLENOBARIS CRYPTODON, n. sp.

Black, shining; tip of rostrum and parts of antennae and tarsi obscurely reddish.

Eyes large and close together. Rostrum moderately wide; curved and slightly shorter than prothorax; with crowded punctures behind antennae, minute elsewhere. Antennae inserted in middle of sides of rostrum. Prothorax slightly longer than wide; with numerous but not crowded punctures of moderate size, becoming larger on sides. Elytra elongate-cordate, distinctly wider than prothorax; with rows of fairly large punctures, vanishing beyond the middle, striae fairly distinct near suture and sides. Metasternum with crowded punctures. Basal segment of abdomen shallowly depressed in middle. Legs rather thin, femora edentate. Length, 2 mm.

♀. Differs in having the rostrum slightly thinner, with smaller punctures on sides, and abdomen evenly convex.

Queensland: Cairns district (F. P. Dodd), Dunk Island (H. Hacker).

Very close to *S. inermis*, but the elytral striation more evident; it is narrower than *S. edentata*, and without the least tinge of blue. On one specimen the prothorax has been detached, and the trochanters of the legs are very prominent, so as to suggest the coxal armature of the males of *Degis trigonopterus*, but it is a female; on two males, not dismembered, the trochanters are not specially evident. The interocular space appears as a narrow shining line, without an impression.

Solenobaris minor, n. sp.

♂. Black, somewhat shining. Under surface and legs with fine white setae, rather conspicuous on the metasternal episterna.

Rostrum about the length of prothorax. Prothorax about as long as wide; with numerous, sharply defined, but not large, punctures, becoming crowded on sides. Elytra elongate-cordate, not much wider than prothorax; with fine striae throughout, on basal half with rather small punctures, vanishing beyond the middle. Metasternum and two basal segments of abdomen with a wide shallow depression. Legs rather thin, femora edentate. Length, 1·8 mm.

Papua: Mount Lamington (C. T. McNamara).

A rather narrow species, the smallest of its genus, and of the subfamily from New Guinea. The eyes are rather large, but the interocular space has numerous punctures, and does not appear as a narrow shining line as on the preceding species; the elytral punctures are also smaller and the striae are more evident.

Solenobaris casuarinae, n. sp.

♀. Black, shining.

Rostrum the length of prothorax; with crowded punctures behind antennae (which are inserted slightly nearer apex than base) and at base. Prothorax as long as wide; with numerous but not crowded punctures of moderate size, becoming small at apex, and crowded on sides. Elytra elongate-cordate; with fine striae throughout, containing fairly large punctures on basal half, disappearing beyond the middle. Metasternum with punctures as on sides of prothorax, becoming smaller and sparser on abdomen, and almost absent from intermediate segments. Femora slightly dentate. Length, 2·2 mm.

New Guinea: Finsch Haven, on *Casuarina* sp. (Rev. L. Wagner). Unique.

Fairly close to the two preceding species, but larger, rostrum slightly longer and femora dentate, the tooth on each is small, but sufficiently distinct from certain directions. The elytral striae are more distinct than is usual in the genus.

SOLENOBARIS SPATHULIROSTRIS, n. sp.

♂. Black, shining; tip of rostrum and parts of antennae and of legs obscurely reddish. Each puncture of under surface and of legs with a small whitish seta.

Rostrum the length of prothorax, sides dilated in front; sides with crowded punctures behind antennae (which are inserted slightly nearer apex than base). Prothorax as long as wide; with sparse and minute punctures, becoming larger near coxae. Elytra elongate-cordate; with fine but distinct striae throughout, containing small punctures on basal half, absent elsewhere. Metasternum with crowded punctures, continued on to base of abdomen, the latter with a shallow depression along middle of two basal segments. Legs rather thin, femora edentate. Length, 2 mm.

♀. Differs in having rostrum slightly longer, with smaller punctures, and abdomen evenly convex.

Fiji: Viti Levu (A. M. Lea).

In general appearance fairly close to *S. inermis*, and with similar striae and femora, but slightly narrower, and rostrum distinctly dilated in front of antennae.

SOLENOBARIS NITIDIVENTRIS, n. sp.

♂. Black, shining.

Rostrum moderately curved, not very thin, the length of prothorax; with crowded punctures, except in front. Antennae inserted about two-thirds from apex of rostrum. Prothorax moderately transverse, somewhat flattened, sides rather strongly narrowed from base to apex; with numerous rather small but sharply defined punctures, becoming crowded on sides. Elytra with sharply defined striae throughout, containing small punctures about base only. Metasternum with crowded punctures on sides, but not very dense in middle. Abdomen shining, two basal segments feebly depressed along middle, the apical one with a large shallow depression. Femora edentate. Length, 2 mm.

Fiji: Viti Levu (A. M. Lea). Two males.

Fairly close to the preceding species, but less convex, more robust, with more distinct punctures on rostrum and prothorax, and smaller on under surface, and elytral striae sharper and almost impunctate.

GYMNOBARIS.

Lea, *Trans. Roy. Soc. S. Aust.*, 1906, p. 96.

GYMNOBARIS LATERALIS, n. sp.

♀. Black, shining; parts of antennae obscurely reddish.

Rostrum moderately stout, the length of prothorax; with fairly dense punctures on sides behind antennae (these inserted one-third from apex), smaller elsewhere. Prothorax moderately transverse; upper surface with sparse and minute punctures, becoming moderately large but not crowded on sides. Elytra cordate, slightly wider than prothorax; with series of rather small punctures in feeble striae, the punctures vanishing posteriorly, but the striae more distinct there; interstices impunctate. Metasternum with crowded punctures of moderate size, becoming sparser on basal segment of abdomen, and sparser and smaller posteriorly. Femora slightly grooved and with minute denticles. Length, 3·5 mm.

Key Island (Dr. W. Horn, from — Pape). Unique.

The denticles of the femora are even smaller than on *G. politus*, and could be easily overlooked, the seriate punctures on the elytra are somewhat larger

than on that species, but on the sides of the prothorax they are much more distinct, although they are practically absent from the upper surface.

AULACOBARIS, n. gen.

Eyes large and fairly close together. Elytra cordate, deeply and widely striated, the interstices acutely ridged throughout. Prosternum with a rather deep and wide depression, abruptly terminated between front coxae. Pygidium almost concealed. Femora dentate.

Very distinct from all other genera of the subfamily known to me by the deep striae, decidedly wider than the interstices, all of the latter being acutely ridged throughout. In catalogues it may be placed near *Gymnobaris*.

AULACOBARIS PICTIPENNIS, n. sp. Text-fig. 33.

♀. Brownish-black; rostrum and legs somewhat paler, basal two-fifths of elytra and antennae red. A narrow vitta of white scales on fourth interstice on each elytron, between middle and apex, a small spot on each side piece of mesosternum, and a smaller one on each side of abdomen.

Rostrum moderately curved, rather thin, slightly longer than prothorax, feebly depressed at its junction with head; with crowded and rather small punctures on sides behind antennae, sparse and minute elsewhere. Antennae inserted slightly nearer base than apex of rostrum, scape almost attaining eye, basal joint of funicle large. Prothorax moderately transverse, sides gently rounded and decreasing in width from base to apex; with rather dense but not crowded punctures, of moderate size and sharply defined. Scutellum slightly transverse. Elytra cordate, base distinctly wider than prothorax; striae containing deep-set, regular punctures. Sterna with dense punctures, slightly larger than on prothorax. Abdomen evenly convex, with much smaller punctures than on sterna. Legs moderately long, femora feebly grooved and acutely dentate, tibiae thin, claws small and close together. Length, 4 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

A beautiful species, one of the few Australasian ones with derm of elytra bicoloured.

ACYTHOPEUS.

Pascoe, *Journ. Linn. Soc.*, xii, p. 61.

ACYTHOPEUS LEUCOMELAS, n. sp. Text-figs. 25, 32.

♂. Black; some parts moderately shining. Upper surface with four spots of white scales, under parts also with white spots at sides, and fairly numerous scales on sterna, parts of abdomen, and of legs.

Rostrum strongly curved, slightly longer than prothorax, considerably thickened towards base; with crowded and rather coarse punctures on thickened portion, becoming small in front. Antennae inserted almost in middle of sides of rostrum. Prothorax distinctly transverse; with crowded punctures of moderate size. Elytra oblong-cordate, not much wider than prothorax; with conspicuous striae, containing deep-set, inconspicuous punctures; interstices with crowded punctures of moderate size about base, smaller but quite sharp posteriorly. Abdomen with a shallow depression along middle of two basal segments, punctures smaller and sparser than on metasternum, crowded and small on apical segment. Femora grooved and edentate. Length, 4-5 mm.

♀. Differs in having the rostrum slightly longer, less dilated towards base, apical half polished and almost impunctate, abdomen evenly convex and legs somewhat thinner.

Aru Islands (H. Elgner); New Guinea: Wareo (Rev. L. Wagner); Papua: Mount Lamington (C. T. McNamara).

The rostrum seems too stout at the base for the species to be referred to *Zena*. Only one species of *Acythopeus* (*bigeminatus*) with elytral markings was described by Pascoe, and that also was from Aru, but was noted as having base of the rostrum "*profunde inciso et valde gibboso*", and so figured. The present species has the base of rostrum thick, but it is not suddenly uplifted, and is separated from the head by a shallow groove, instead of an acute notch. There is a white spot on each side of the base of the prothorax, and two small ones on each side in front (but invisible from above), on each elytron the spot is on the third interstice beyond the middle; the metasternal episterna are densely clothed, and there is a spot on each side of the first and third segments of abdomen. On two of the specimens, from Wareo, the elytra are almost immaculate, and on one of them the abdomen also is immaculate; on another there is a small spot at the base of the third interstice on each elytron, and a small one on the fourth beside the postmedian one on the third; on another there are two very small spots on the third interstice. On the only specimen from Mount Lamington there are two spots on the third interstice, the postmedian one being long and narrow. From some directions the pronotum appears to be covered with granules instead of punctures.

Acythopeus melas, n. sp. Text-fig. 9.

♂. Black and slightly shining.

Rostrum moderately curved, slightly longer than prothorax, slightly thickened towards base, junction with head marked by a transverse impression; with crowded punctures of moderate size, becoming small in front. Antennae inserted one-third from apex of rostrum. Prothorax slightly transverse; with dense punctures of moderate size, becoming confluent on parts of sides. Elytra cordate; with conspicuous striae, containing deep-set punctures, interstices with rather large punctures about base, smaller posteriorly, but all distinct. Metasternum with punctures as on sides of prothorax, less crowded and smaller on two basal segments of abdomen, which are shallowly depressed along middle. Femora feebly grooved and slightly dentate, front tibiae with a slight incurvature towards apex of under surface. Length, 5·5 mm.

New Guinea: Fergusson Island (Dr. W. Horn, from — Pape). Two males.

Structurally near *A. aterrimus*, but considerably larger, less opaque, junction of head and rostrum more conspicuous, and punctures of upper surface somewhat different.

Acythopeus insignis, n. sp. Text-fig. 26.

Black, slightly shining. Upper surface with dense and fine blackish setae, slightly longer on prothorax than on elytra, the latter with a narrow white vitta at base of third interstice.

Rostrum with a strong ridged crest at base, suddenly and strongly uplifted at its junction with head, then rapidly narrowed in front; behind antennae (which are inserted slightly nearer base than apex) with crowded and fairly large punctures. Prothorax transverse, parallel-sided to near apex, which is suddenly

narrowed and not half the width of base; punctures transversely confluent, and separated by numerous fine ridges. Elytra subcordate, shoulders slightly produced, with fine striae, containing distinct punctures only near base, where the interstices have crowded ones. Sterna with crowded punctures, sparser on basal segment of abdomen, and still sparser and smaller on the other segments. Front coxae widely separated, femora slightly grooved and edentate. Length, 3·5 mm.

Papua: Bisiatabu (Rev. W. N. Lock). Unique.

A remarkable species, for which it may be necessary to propose a new genus. The toucan-like crest occupies about two-fifths of the base of the rostrum. The punctures of the transversely oblong prothorax are so confluent that the surface appears traversed by numerous fine carinae; the sides, however, appear granulate. The basal segment of the abdomen is flattened along middle, and as there are no masculine features on the front tibiae the type is probably a female.

ACYTHOPEUS UNGUICULATUS, n. sp. Text-figs. 20, 21.

♂. Velvety-black. With dense and extremely minute setae.

Head with crowded punctures. Rostrum moderately stout and curved, the length of prothorax, the sides parallel to in front of antennae (which are inserted about one-third from the base) and then incurved, a faint depression at its junction with head; basal half with crowded punctures and opaque, apical half shining and with smaller but sharply defined punctures. Prothorax moderately transverse, rather strongly convex, hind angles produced, sides rapidly decreasing in width to apex; with crowded and fairly large punctures, in places obliquely confluent. Elytra oblong-cordate; with regular rows of large, subquadrate punctures, the interstices narrower than the rows, and each with a series of small granules. Sterna with large thimble punctures. Basal segment of abdomen feebly depressed along middle, its sides with punctures as on metasternum, but much smaller elsewhere, and shining. Front coxae moderately separated; femora slightly grooved and edentate, tibiae with lower edge slightly sinuous, an acute notch near apex, the apical hook unusually long; tarsi rather short, claw joint strongly dilated (but not thickened) to apex, with the claws small. Length, 5·5 mm.

Malay Peninsula: Gap, on Fraser's Hill (A. M. Lea). Unique.

The clothing of the upper surface is so short that even from the sides it is visible with difficulty. The rostrum from directly above appears parallel-sided, but from other directions the sides are seen to be incurved between the middle and apex. The granules on the elytra are invisible from some directions, but from others appear shining and distinct. Each claw joint from the side appears very wide, but from directly above appears normally thin.

ACYTHOPEUS RUDIS, n. sp.

♀. Black, shining. With a few dark setae.

Head smooth. Rostrum rather strongly curved, slightly longer than prothorax, somewhat dilated to base, its junction with head traversed by a shallow groove; with crowded and rather coarse punctures behind antennae (which are inserted slightly nearer apex than base). Prothorax moderately transverse, sides almost evenly rounded, apex about half the width of base; with coarse, crowded punctures, in places confluent, with short bounding ridges. Elytra cordate; with fairly wide striae, containing deep-set punctures; interstices with large punctures about base, smaller posteriorly. Sterna with crowded punctures, somewhat smaller than on

prothorax. Abdomen evenly convex, shining; with sparse and minute punctures, becoming somewhat larger and crowded on apical segment, and forming a row across the middle of the third and fourth. Femora feebly grooved and edentate. Length, 4 mm.

Java: Buitenzorg (A. M. Lea). Unique.

The punctures on the upper surface are coarser than on any other species of the subfamily before me, but on the head they are so minute as to be practically invisible. The elytra, from the sides, appear subtuberculate towards the apex, the interstices about the base are flattened, with seriate punctures occupying almost their entire width, but posteriorly they become ridged, narrower than the striae, with the punctures small and on their sloping sides.

ACYTHOPEUS BIGEMINATUS Pasc.

Baris praemorsa Lea, var.

Ten specimens from Mount Lamington probably belong to this species; each has a deep incision at the junction of the head and rostrum, exactly as figured, and each elytron has two snowy spots on the third interstice; in addition, however, there is a small spot at about the basal third on the ninth interstice, and usually a few white scales about the apex. On each side of the prosternum, concealed from above, there is also a small white spot. The length varies from 3·0 to 4·5 mm.

Baris praemorsa, from Torres Straits, appears to be a slight variety of the species.

MYCTIDES.

Pascoe, *Journ. Linn. Soc.*, xii, p. 59.

MYCTIDES FILIROSTRIS, n. sp. Text-fig. 27.

♀. Black, shining, scape obscurely reddish. Legs with small white setae, becoming longer on parts of under surface.

Rostrum very long, thin, and evenly curved, a feeble depression at its junction with head; with fairly dense but small punctures on sides behind antennae (these inserted about one-third from base), minute elsewhere. Prothorax moderately transverse; with rather small and sparse punctures on disc, but leaving a shining impunctate median line, and becoming crowded on sides. Elytra cordate; with sharp striae containing distinct punctures about base and suture, but feeble elsewhere; interstices with small punctures about base and apex. Under surface with dense punctures. Legs rather long, femora slightly but acutely dentate. Length, 4·5 mm.

New Guinea (Dr. W. Horn, from — Kraatz). Unique.

The rostrum is much longer than on any previously described species of the genus, extending to the apex of the elytra.

MYCTIDES BARBATUS Pasc.

Numerous specimens from Aru, Port Moresby and Finsch Haven appear to belong to this species, but have the upper surface somewhat brassy.

METANTHIA.

Pascoe, *Journ. Linn. Soc.*, xii, p. 57.

The species of this genus are fairly numerous in New Guinea and adjacent islands. Their elytra are slightly wider near the base than elsewhere, but with

outlines continuous with those of prothorax; the elytral punctures are seriate in arrangement, but are not set in striae, which are usually completely absent. The front coxae are rather close together, and there is a shallow pectoral groove, although to see this clearly it is necessary to remove the head. The rostrum is fairly stout on *M. pyritosa* (the first named and so presumably the typical species) but is longer and thinner on some of the others. Most of the species are deep shining-black, but several are metallic (*pyritosa* brilliantly so).

METANTHIA GRANULIPES, n. sp. Text-fig. 10.

♂. Black, with a purplish or bluish gloss, absent from most of rostrum, antennae, and under surface of legs.

Rostrum slightly dilated to base, the length of prothorax; with moderately large punctures on sides behind antennae. Prothorax moderately transverse, sides rapidly diminishing in width from base to apex, scutellar lobe transversely depressed; with sparse and minute punctures, even on sides. Elytra elongate-cordate; with rows of small punctures, larger near suture than elsewhere, the interstices with scarcely visible ones. Metasternum with fairly dense and large punctures, somewhat similar on basal and apical segments of abdomen, on the others sparse and minute; two basal segments depressed along middle, the apical one with a fairly large fovea. Legs moderately long, front coxae rather close together, femora grooved and edentate, front tibiae with an obtuse projection on lower edge near apex. Length, 7–8 mm.

♀. Differs in having the rostrum thinner and distinctly longer (about one-fourth longer than the prothorax), abdomen evenly convex, except for a small medio-apical depression on the basal segment, and front tibiae simple.

New Guinea: Wareo (Rev. L. Wagner); Papua: Mount Lamington (C. T. McNamara).

The shorter distance separating the front coxae and the complete absence of elytral striation (although the series of punctures are distinct) have induced me to refer this species to *Metanthia* rather than to *Ipsichora*. The rostrum is longer than on *M. pyritosa* (especially on the female) and is not raised at the base on the male, and but little on the female. The blue is more evident on the female than on the male, but is not brilliant. The femora, although not denticulate, are margined on each side of the groove with a row of small granules.

METANTHIA REGULARIS, n. sp. Text-fig. 11.

Black, shining.

Rostrum moderately stout, about the length of prothorax; with crowded punctures of moderate size on sides behind antennae. Prothorax scarcely wider at base than the median length, sides evenly decreasing in width to apex; scutellar lobe not depressed; with rather sparse and small, but sharply defined, punctures, becoming larger on sides. Elytra with regular series of rather small punctures, the interstices with minute ones. Under surface with crowded punctures, smaller and sparser on parts of abdomen than elsewhere, basal segment depressed along middle, apical with a fairly large fovea. Legs moderately long, femora grooved and edentate, front tibiae with a small tooth close to the apical hook. Length, 4·5–5·0 mm.

♀. Differs in having rostrum slightly thinner, abdomen evenly convex, and front tibiae simple.

Aru Islands (H. Elgner).

Structurally close to *M. pyritosa*, but slightly smaller, and deep-black, although with a faint metallic gloss.

METANTHIA GAGATINA, n. sp. Text-fig. 28.

♂. Black, shining.

Rostrum rather stout, the length of prothorax; with small punctures, more crowded behind antennae than elsewhere. Prothorax moderately transverse, sides rapidly diminishing in width to apex, scutellar lobe transversely depressed; punctures sparse and minute, even on sides. Elytra elongate-cordate, with rows of small distant punctures, those forming the row near suture larger than the others. Metasternum with crowded punctures, almost as large on basal segment of abdomen but sparser there, that segment with a rather wide median depression, apical one with a large median fovea and rather dense punctures. Front coxae close together, femora shallowly grooved and edentate, front tibiae with a distinct tooth on lower surface one-third from apex. Length, 5·0–5·5 mm.

♀. Differs in having rostrum slightly longer, abdomen evenly convex, except for a slight depression on apical segment, and front tibiae simple.

New Guinea: Wareo (Rev. L. Wagner).

Structurally close to *M. pyritosa*, but deep-black; the tooth on the front tibiae of the male, and the depressed scutellar lobe, readily distinguish it from the preceding species.

METANTHIA SCUTELLARIS, n. sp. Text-fig. 12.

♂. Black, shining.

Head with a small but deep interocular impression. Rostrum not very stout, slightly longer than prothorax, a feeble depression at its junction with head; with crowded punctures on sides behind antennae, small elsewhere. Prothorax distinctly transverse, apex scarcely half the width of base; with sparse and minute punctures, becoming larger near coxae, and forming a fairly distinct row across a slight subapical depression. Elytra cordate; with rows of small punctures, the row near suture distinct, the others slight; interstices scarcely visibly punctate. Metasternum with fairly dense punctures, continued on to basal segment of abdomen, the latter with a shallow median depression. Legs rather long, femora slightly grooved and edentate, front tibiae with a distinct tooth on lower surface about one-fourth from apex. Length, 4–5 mm.

♀. Differs in having the rostrum somewhat longer and thinner, abdomen evenly convex, and front tibiae simple.

Papua: Mount Lamington (C. T. McNamara).

Slightly stouter than the preceding species, rostrum thinner, antennae inserted not as close to apex of rostrum, tooth of front tibiae of male slightly nearer the apex, and apical segment of abdomen nonfoveate. The scutellar lobe has a feeble depression, and the scutellum itself is distinctly transverse.

METANTHIA APINA, n. sp. Text-fig. 29.

♀. Black, shining; scape reddish.

Rostrum comparatively thin, gently curved, the length of prothorax, scarcely depressed at its junction with head; with crowded and rather small punctures on sides behind antennae (these inserted almost in middle), smaller and sparser elsewhere. Prothorax moderately transverse, sides rapidly diminishing in width

to apex; with sparse and minute punctures, even on sides. Elytra cordate; with rows of small punctures, becoming minute in places; interstices impunctate. Metasternum with fairly large but not crowded punctures, becoming smaller and sparser on basal segment of abdomen, dense on apical one, and sparser elsewhere. Legs rather long, front coxae close together, femora widely and shallowly grooved and edentate. Length, 5 mm.

New Guinea: Wareo (Rev. L. Wagner). Unique.

The rostrum is rather thin and less curved than on other species of the genus, but the other generic characters are not aberrant. The type differs from the female of *M. gagatina* in having the rostrum decidedly thinner, scutellar lobe not at all depressed, and abdomen with somewhat different punctures. From the female of the preceding species, it differs by the rostrum, elytral punctures smaller, and those of apical segment of abdomen larger. The upper surface has a slight metallic gloss, which becomes more distinct when wetted.

METANTHIA PYRITOSA Pasc. Text-fig. 13.

One of the most brilliantly metallic weevils in New Guinea and widely distributed. "Dorey, Saylee," Madang, Mount Lamington, and Aru. Pascoe described the rostrum as "*sparse subtiliter punctato*". This is true of its upper surface, but its sides on the basal half are rather coarsely and densely punctate. The male differs from the female in having the rostrum somewhat stouter, with stronger punctures on the sides, basal segment of abdomen longitudinally impressed in the middle, legs slightly stouter, and the front tibiae with a small projection one-third from the apex. The specimens before me are all smaller, up to 5 mm., than the type, 3½ lines, but Pascoe often measured his specimens with the rostrum extended.

IPSICHORA.

Pascoe, *Journ. Linn. Soc.*, xii, p. 58.

IPSICHORA LONGIPES, n. sp. Text-fig. 17.

♂. Bright metallic-blue; antennae and tarsi blackish.

Rostrum thin, moderately curved, about one-fourth longer than prothorax, a shallow depression at its junction with head; with rather sparse punctures on sides behind antennae (these inserted one-third from apex), sparser and smaller elsewhere; under surface with two rows of minute granules. Prothorax moderately transverse; with small and rather sparse punctures. Elytra subcordate, outlines continuous with those of prothorax; with series of small punctures in fine striae, the punctures absent from parts, but the striae complete; interstices with minute punctures. Sterna with sharply defined but not very large punctures, larger (but irregular) on side pieces of mesosternum than elsewhere. Abdomen with small and sparse punctures, the basal segment with a large, slightly clothed median depression. Legs long, especially the front ones, front coxae widely separated, femora with a row of granules terminating in acute denticles on one side of a shallow groove, very feeble on the other side, front tibiae with a row of minute granules on lower edge; front tarsi with long black hair on each side of three basal joints. Length, 6·0–8·5 mm.

♀. Differs in having the rostrum thinner, more evenly curved, and black or mostly black, antennae inserted less close to apex, prothorax smaller, abdomen evenly convex, front legs but slightly longer than the others, and front tarsi clothed as the others.

New Guinea: Finsch Haven (Rev. L. Wagner). Abundant.

Apparently close to *I. cupido* (presumably the type of the genus) but the rostrum in the male is usually metallic throughout, and the pronotum is not sulcate. The femora are grooved, apparently the main distinction from *Pseudocholus*; the typical species of that genus was described as having "*prosterno antice abdomineque basi rugosis*". *P. viridimicans* was described as having head, rostrum and legs black, prothorax foveate, and the front tarsi with two joints clothed with long hair; on the present species three joints are so clothed. On many specimens parts of the under surface and legs are greenish, the elytra are often purplish, on the male the rostrum is occasionally blackish about the apex, on the female it is sometimes entirely black. The front sides of the prothorax, invisible from above, are fairly densely covered with small granules on the male, but not on the female.

IPSICHORA TIBIALIS, n. sp. Text-fig. 18.

♂. Metallic-blue; part of rostrum, antennae and tarsi black.

Rostrum moderately curved, distinctly longer than prothorax, a wide but shallow depression at its junction with head; with crowded, but not very large, punctures on sides behind antennae (these inserted about two-fifths from apex), minute elsewhere. Prothorax moderately transverse, with small and sparse punctures, becoming larger and denser near coxae. Elytra subcordate, with rows of distinct punctures in fine striae, the punctures becoming very small posteriorly; interstices with scarcely visible punctures. Side pieces of mesosternum with larger punctures than on rest of sterna. Abdomen with smaller punctures, except at sides of base, than on metasternum, basal segment shallowly depressed in middle. Legs not very long, front coxae widely separated, femora with a row of granules terminating in minute denticles on each side of the groove, front tibiae with a conspicuous fringe of grey hairs on apical half of lower surface, three basal joints of front tarsi also fringed. Length, 7 mm.

♀. Differs in having rostrum longer, thinner, more strongly curved, antennae inserted nearer base than apex of rostrum, abdomen rather strongly convex, and front tibiae and tarsi simple.

Papua: Mount Lamington (C. T. McNamara).

In general appearance close to the preceding species, but front legs of the male much shorter, front tibiae with the apical half fimbriated, front tarsi with shorter and paler clothing, and antennae somewhat shorter; the female has more pronounced elytral striae, with larger, although not very large, punctures in the striae. On the type the under parts are of the same shade as the upper ones, but on the female they are bluish-green.

IPSICHORA CARINICOLLIS, n. sp.

♂. Dark purplish-blue; most of under surface, legs and rostrum black, in parts with a slight metallic gloss, head dark-brown.

Rostrum about one-third longer than prothorax, thin in front, moderately dilated to base; with fairly dense but not large punctures behind antennae (these inserted about two-fifths from apex). Prothorax (with head) subtriangular; with rather sparse and small punctures, even on sides; with a fine continuous median ridge. Elytra with outlines continuous with those of prothorax, but considerably wider near base; with comparatively small even punctures, in sharp striae; interstices with sparse and small, but sharp, punctures. Sterna with

comparatively sparse and small punctures, even on side pieces of mesosternum, and absent from most of abdomen, two basal segments with a wide and shallow median depression. Legs rather long and thin, front coxae widely separated, femora with a few granules and denticles on each side of a feeble groove, front tibiae with a sparse fringe on apical half of lower surface. Length, 8 mm.

New Guinea (Dr. W. Horn, from — Kraatz). Unique.

The elytral striation and punctures are more pronounced than on the other species before me, and the prothorax has a fine and continuous median carina. There is a slight projection near the front coxae on each side of the breast, but it could be easily overlooked. The club of the antennae has a shallow oblique groove.

IPSICHORA PILIVENTRIS, n. sp. Text-figs. 19, 20.

♂. Black, shining.

Rostrum moderately thin, about the length of prothorax; with crowded punctures on sides behind antennae (these inserted one-third from apex), sparse and minute elsewhere. Prothorax feebly convex, rather strongly transverse, apex suddenly and strongly narrowed; with sparse and minute punctures, even on sides. Elytra subcordate; with small punctures in fine striae, the interstices scarcely visibly punctate. Sterna with fairly dense punctures of moderate size, larger on mesosternum than elsewhere. Abdomen, except about base, with smaller and sparser punctures than elsewhere; two basal segments with a shallow median depression, clothed with fairly long depressed hairs. Legs comparatively short, front coxae widely separated, femora grooved and acutely dentate, front tibiae with upper edge gently incurved, lower edge fringed on apical half, three basal joints of front tarsi fringed. Length, 6·5 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

A highly polished, jet-black species, with front tibiae and tarsi fringed much as on *I. tibialis*.

PSEUDOCHOLUS.

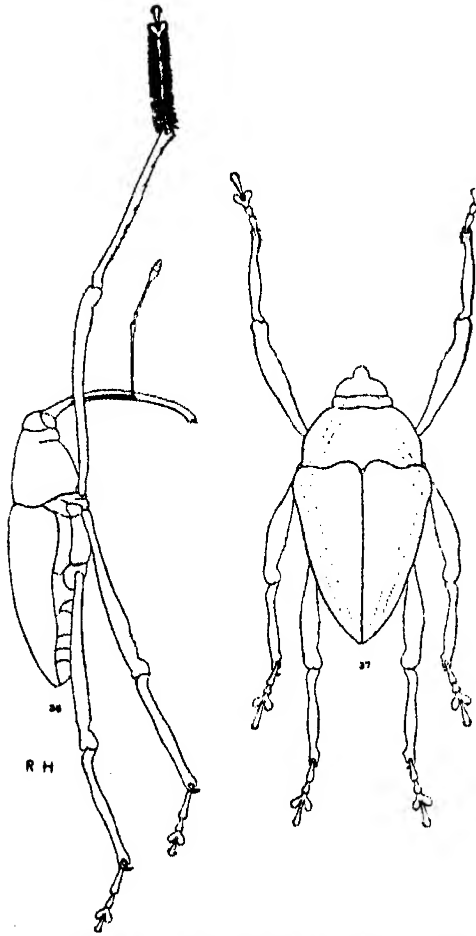
Pseudocholus, Lacordaire, *Gen. Col.*, vii, p. 253.

PSEUDOCHOLUS FIMBRITARSIS, n. sp. Text-fig. 36.

♂. Black, with a faint coppery gloss.

Head with a small, deep, interocular puncture, its junction with rostrum flattened. Rostrum thin, about half as long again as prothorax; with fairly large punctures on sides behind antennae, small elsewhere. Antennae inserted slightly nearer apex than base of rostrum, scape the length of funicle and club combined. Prothorax slightly dilated from base to near middle, and then rapidly narrowed to apex; with fairly large and dense punctures about base, smaller and irregular elsewhere. Scutellum transverse. Elytra cordate, with striae containing almost regular punctures of moderate size, becoming larger at base; interstices with crowded and rather coarse punctures about base, a few distinct ones at apex, absent elsewhere. Sterna with irregular punctures, sparse and small in places, larger on side pieces of mesosternum than elsewhere; prosternum widely and shallowly depressed in front of legs. Abdomen with rather small punctures, basal segment shallowly depressed in middle. Legs very long and thin, front coxae widely separated, femora with small denticles, front tibiae with numerous acute denticles on under surface, front tarsi with a conspicuous fringe of pale hairs on

each side of the three basal joints, the first of these longer than the rest combined. Length, 9-10 mm.



Text-fig. 36.—*Pseudocholus fimbritarsis* Lea.
Text-fig. 37.—*P. cinctus* Pasc.

♀. Differs in having rostrum thinner, more evenly curved, with smaller punctures, antennae shorter, and inserted almost in exact middle of sides of rostrum, abdomen rather strongly convex, legs shorter, but still decidedly long, front tibiae not denticulate and front tarsi not fimbriated.

Papua: Mount Lamington (C. T. McNamara).

Distinct from all previously described species by the front legs of the male.

PSEUDOCHOLUS CINCTUS Pasc. Text-fig. 37.

Eight specimens, from the Finsch Haven district, probably belong to this species, distinct by the stramineous vitta continuous on each side from apex of

prothorax to apex of elytra; but they differ from the description in having the under surface black with a slight metallic gloss, not "*fusco castaneo*" (probably the type was immature). The rostrum was described as being "*vix latiore*" than the prothorax, no doubt in error for "*vix longiore*".

The male differs from the female in having the rostrum somewhat stouter, with coarser punctures towards the base, antennae inserted nearer its tip, metasternum with a deeper and wider longitudinal depression, continued on to basal segment of abdomen, and partly clothed, and longer legs.

PSEUDOCHOLUS QUERULUS Pasc.

Nine specimens from Mount Lamington belong to this species, of which there is one of the original specimens, from Yule Island, before me.

The male differs from the female in having the rostrum stouter, with coarser punctures, its under surface finely serrated, metasternum with a deeper and wider longitudinal depression, continued on to basal segment of abdomen, and partly clothed, legs longer, and basal joints of front tarsi fimbriated.

DEGIS.

Degis, Pascoe, *Ann. Mus. Civ. Gen.*, 1885, p. 294.

DEGIS COXALIS, n. sp. Text-figs. 14, 16.

♂. Black, shining; prothorax subopaque, antennae reddish.

Rostrum not very stout, slightly longer than prothorax, its junction with head traversed by a shallow depression; with crowded but not very large punctures on sides behind antennae, sparser and smaller elsewhere. Prothorax moderately transverse, sides strongly narrowed at apex; with rather dense but not crowded punctures, of moderate size or rather small, becoming sparser and smaller on sides. Elytra oblong-cordate; with sharp and almost impunctate striae, the interstices with almost invisible punctures. Metasternum with punctures as on sides of prothorax, becoming sparser and smaller on basal segment of abdomen, which has a wide and shallow depression, intermediate segments almost impunctate. Legs moderately long, front coxae slightly armed, femora acutely dentate, middle tibiae rather strongly arched at base. Length, 5·0–5·5 mm.

♀. Differs in having the rostrum slightly longer and thinner, abdomen evenly convex and front coxae simple.

Papua: Mount Lamington (C. T. McNamara); New Guinea: Wareo (Rev. L. Wagner).

There is a small conical projection on the front coxae of the male, but it is much smaller, although quite distinct, than the conspicuous projection on *D. trigonopterus*, its prosternum is almost glabrous and the femora are acutely dentate, the hind ones less strongly than the others. The prothoracic punctures are smaller and sparser on the sides than on the upper surface, an unusual feature in the subfamily. The specimen from Wareo has most of the under surface reddish, probably from immaturity.

The type has a conical process projecting downwards from the tip of the rostrum; it is possibly deciduous, as it is not present on a second male, or on the female.

DEGIS IMITATOR, n. sp. Text-fig. 15.

♀. Black, shining; prothorax subopaque, antennae obscurely reddish. Upper surface of hind femora with rather dense white clothing, rest of legs and under surface inconspicuously setose.

Rostrum the length of prothorax, feebly depressed at its junction with head. Elytra with sharply defined striae, the interstices with minute punctures. Metasternum with punctures as on sides of prothorax. Abdomen with sparse and small punctures, basal segment feebly depressed in middle of apex. Femora grooved and edentate. Length, 5 mm.

Papua: Mount Lamington (C. T. McNamara).

Strikingly close to the preceding species, but with edentate femora. I have named this species, although there are but two females before me, as the species is so like the preceding one, that I had them placed as belonging to it. In addition to the femora, however, the tibiae are also different; on that species each tibia at the base is convex outwardly; on the present species its outer edge has a slight inward curve. The prothoracic punctures are also slightly larger than on that species and on the sides are slightly larger still, although not crowded. The elytral striae appear minutely serrated, owing to the punctures slightly encroaching on their sides; this appearance, however, vanishes posteriorly and laterally.

DEGIS RESIDUUS, n. sp.

♂. Black, shining; prothorax subopaque, antennae obscurely reddish.

Rostrum about the length of prothorax, a shallow depression at its junction with head; with crowded punctures on sides behind antennae, small elsewhere. Prothorax slightly transverse; with crowded punctures of moderate size or rather small. Elytra sharply striate, the interstices without punctures, except a few on sides at apex. Metasternum with crowded punctures. Abdomen with smaller and sparser punctures, the two basal segments depressed along middle. Legs rather long, femora acutely dentate, the hind ones less noticeably than the others, upper edge of tibiae feebly incurved. Length, 3 mm.

Papua: Mount Lamington (C. T. McNamara). Unique.

Considerably smaller than the two preceding species. There is a minute projection on each of the front coxae, but it could be easily overlooked, and is invisible from most directions. The prothoracic punctures and elytral striae, however, are typical of the genus.

DEGIS TRIGONOPTERUS Pasc. Text-figs. 34, 35.

Eight specimens, from Mount Lamington, Finsch Haven, and the Port Moresby and Madang districts, appear to belong to this species, but have the scutellum slightly longer than wide, instead of transverse. The males have a conspicuous tooth on each front coxa, clothed with white hair in front, and most of the prosternum is similarly clothed. Each shoulder has a conspicuous swelling that, with the insect on its back, appears as a large obtuse tubercle (this is not shown in the original figure), and the basal segment of the abdomen is longitudinally impressed. The female is without coxal armature, the prosternum is almost glabrous, and the abdomen is evenly convex. Both sexes have two rows of minute teeth on the femora, the teeth terminating at the subapical notch.

THE LIFE HISTORY OF *CALLIPHORA OCHRACEA* SCHINER (DIPTERA, CALLIPHORIDAE).

By MARY E. FULLER, B.Sc.,
Junior Entomologist, Council for Scientific and Industrial Research, Canberra, F.C.T.

(Two Text-figures.)

[Read 27th May, 1931.]

1. *Introduction.*

The earliest reference to *Calliphora ochracea*, other than purely systematic, occurs in a pamphlet by W. W. Froggatt, published in 1914, in which he gives a coloured plate including this species, and states that nothing is known about its life history. In 1915 he noted, in another publication, that it appears to frequent shaded gullies and timbered country, but has never been found breeding in carcases or live sheep. He kept specimens in captivity in an attempt to induce them to oviposit on meat, but without success. Hardy, in 1926, also mentions the fact that no one has succeeded in breeding *Calliphora ochracea*, but in 1930 claims that it is a notorious blower of blankets. These facts seem difficult to reconcile.

Attempts to breed the fly here under insectary conditions having been successful, the present paper gives the life history and description of the various stages.

2. *Systematics and Synonymy.*

Calliphora ochracea Schiner is separated, along with the closely related *C. nigrithorax* Mall. from all other Australian species of *Calliphora* by the hairiness of the eyes. In general form it is also very distinctive, so that Brauer and Bergenstamm made it the type of a new genus *Neocalliphora*, and Surcouf later transferred it to the subgenus *Adichosia*.

Calliphora ochracea was described by Schiner in 1868 from females collected in Sydney. Macquart, in 1850, had described *Ochromyia hyalipennis* from a female from Tasmania. In 1914 Surcouf added further details to Macquart's description from the type females.

Johnston and Hardy, in 1922, placed the two species *ochracea* and *hyalipennis* in the genus *Neocalliphora* of Brauer and Bergenstamm. In 1925 Patton included the hairy-eyed blowflies in the genus *Calliphora*, and stated that *C. hyalipennis* Macq. is the well-known reddish-brown blowfly of Australia. He stated that the types of *hyalipennis* are typical specimens of *ochracea*, and so the former name must replace Schiner's.

Hardy, in 1926, also included all the species under *Calliphora* and pointed out the difference between the two species *hyalipennis* and *ochracea*. He noted Patton's sinking of *ochracea* as a synonym of *hyalipennis*, but the fact remains that two valid species occur; one in Tasmania and one on the mainland. Hardy

also pointed out in this paper that Macquart had used the name *hyalipennis* earlier for another species.

Malloch, in 1927, was of the opinion that the Tasmanian and mainland forms were distinct species, but owing to scantiness of material would come to no definite conclusion. He called the Tasmanian one *nigrithorax* and listed it as a form of *ochracea*.

In a paper published just previous to that of Malloch, Bezzi stated that he had a female of a species, which he called *Calliphora* (*Adichosia*) *hyalipennis* Macq. 1850, *nec* 1834, from Sydney, that it is recorded from Australia and Tasmania, and that *ochracea* Schiner is a synonym.

The descriptions of Macquart and Schiner, applied respectively to long series of *C. nigrithorax* and *C. ochracea* before me, leave no doubt as to the validity of these two species. With the exception of one female in the Australian Museum, all the *nigrithorax* are from Tasmania. This specimen, labelled Barrington Tops, N.S.W., appears to be the first record of the species from the mainland.

The work embodied in this paper was carried out on *Calliphora ochracea* Schiner.

3. *Distribution.*

According to all the records and collections, this species occurs along the coast and tablelands of New South Wales and Queensland. It does not appear to extend west of the Main Divide, and as far as I know there are no records of it from Victoria. The most northerly record noted is near Mackay, N.Q. Although there are few accounts of its occurrence south of Sydney, it has recently been collected at Pambula not far distant from the Victorian border, but farther south it was not seen.

Although it occurs right on the coast, *Calliphora ochracea* seems to be most abundant in elevated, timbered country. It has been collected by the writer at Sydney and Barrington Tops at the same time of the year, and the difference in abundance was very noticeable. So, although *C. ochracea* has been referred to as a somewhat rare blowfly, this is not true for certain localities where conditions are apparently most suitable for it. It has not been found in the Federal Capital Territory, this region being too far west and doubtless too dry for the species.

C. ochracea has an early spring and autumn cycle. The writer has taken it in numbers only in the early spring, at the end of July and in August, but a few odd specimens have been caught in certain localities in summer. The great majority in collections, however, are labelled March and April.

4. *Method of Breeding the Fly.*

In July and August, 1929, several females of *C. ochracea* were caught in company with *C. stygia* on the windows of a house in Northbridge, Sydney. It was decided to use such a favourable opportunity to try to discover some facts about its hitherto unknown life history. With this object in view two females were confined in a jar containing a piece of moistened meat wrapped in muslin. Jam was smeared on the side of the jar as food for the adults, which were observed to feed from this immediately. The top of the jar was covered with muslin. The following day one of the flies was observed ovipositing on the jar cover by thrusting the ovipositor right through the muslin and placing the eggs on the outside. Two days later the eggs hatched and both flies died.

On 7th August another female was put into a jar containing fresh beef wrapped in muslin and moistened with cabbage water. A piece of rabbit fur was placed on top of this. The fly was fed on sugar-water, jam and boiled sweets. Three days later it deposited a batch of eggs in the fur. The same evening the fly and the two jars were taken to Canberra. The same fly was given a jar in the blowfly insectary containing meat, muslin and fur. On 4th September it produced a fresh batch of eggs and died the next day. Since this particular fly had lived thirty days and oviposited twice since being captured, a note on the method of keeping it alive in captivity may be of interest. A comparatively large proportion of carbohydrate food seemed essential. It was observed to feed for quite long intervals on honey and jam, and although it was occasionally noticed sucking juices from the meat and cabbage, this food was definitely not sufficient to support it alone. Quite large pieces of sugar were absorbed by this fly at one meal, and it was found necessary to provide it with a fresh supply of such food each day. Each day it was released from the jar and allowed to fly round the insectary in the sunlight for a time.

At the end of August, 1930, a female was caught in Northbridge and brought to Canberra. It readily oviposited on rabbit fur placed on a piece of steak. This fly produced one batch of eggs only, and died in a few days.

Early in September, another female was received from the same locality. Five days later it produced a batch of eggs. The cold weather seemed to affect this fly seriously, but on removing it from the insectary to a constant temperature chamber at 23° C. it revived and, four days after producing the first mass of eggs, it oviposited again and died soon afterwards.

In every batch the larvae fed to full size on the decomposing beef present when the eggs were deposited.

When more than four hundred adults emerged from these last two batches every effort was made to induce this generation of flies to breed. It became evident that the heat and humidity of the constant temperature room suited them better than conditions in the insectary, doubtless approaching more closely their natural environment. They lived for lengthy periods under these conditions, feeding readily from the materials provided, including a variety of carbohydrate and nitrogenous foods. But mating was never observed, and females dissected at different periods showed no signs of egg development. Eventually, however, some eggs were deposited in fur but these failed to develop.

5. *Length of Stages in Life Cycle.*

The following observations were made on the flies bred in 1929. The eggs took two days to hatch. In Batch 1 the maggots hatched on 6th August and were still feeding on 29th. By 3rd September they were prepupal, on 16th the first puparium was seen, and on 20th several had pupated. The first emergence took place on 2nd November. In Batch 2 the maggots hatched on 12th August, and all, with the exception of some which appeared unhealthy, were prepupal on 20th September. Puparia were present on 27th, and on 28th October the first adults emerged. In Batch 3 the maggots hatched on 6th September. They increased in size very slowly and when six days old were not much larger than when hatched. In warm weather other species will grow to full size and pupate in this time. Obviously the cold weather during which it breeds retards the larval development of *ochracea*. During the next three days they increased noticeably in size. On 2nd October most of the maggots in this batch had disappeared into the sand

to pupate, and by 17th all had pupated. Ten adults emerged on 4th November. The last fly from these three batches died on 17th December.

The average larval life, that is the active feeding stage, was 30 days. The prepupal period occupied about 13 days, but the pupal period varied a good deal in duration. Those larvae which pupated early, that is about the middle of September, emerged at the same time as those which had not reached the pupal stage until the middle of October. The rapidity of development of the fly in the puparium was dependent on temperature, so that those which had pupated some time earlier than the others did not develop any more quickly owing to the cold weather. Thus there were flies emerging from all three batches at the same time in the first two weeks of November.

Altogether from the three batches of maggots produced by two females 74 flies emerged, 46 males and 26 females. In addition there were 60 dead prepupal maggots, 47 aborted puparia and 34 puparia containing dead flies. Thus on an average there were 72 eggs produced in each batch. The flies of this generation lived from four to six weeks in the insectary, but with one exception did not oviposit. One female laid eggs on a guinea pig. They were attached close to the skin on the hairs, were very pale in colour and did not hatch.

6. *Effect of Temperature and Humidity on Rate of Development.*

Since the rate of development of *C. ochracea* is slower than most blowflies, an experiment was carried out to see if this is correlated with the low temperature conditions of the season during which it breeds.

A batch of eggs produced on 28th August, 1930, was divided into two lots; one lot was kept in the insectary and the other in a higher temperature chamber. The developing maggots were kept under close observation and a record of the dates at which they reached the various stages made for comparison. There was a striking difference in the maggots of the two batches after four days. Those in the insectary were a few millimetres long, whilst those in the warm room were in their third instar.

The temperature in the warm room, except for very slight fluctuations, remained at 23° C. during the whole period. The humidity was higher than that in the insectary, but varied somewhat. It was always above 70% and generally between 70% and 80%. The insectary temperature was not controlled and fluctuated considerably, becoming higher as the season advanced. The minimum ranged from −1·6° to 9° C. in September and reached 11° C. in October. The maximum rose from 12° to 31° C. whilst the fly was breeding.

A comparison of the periods of development in the two cases is as follows:

	Constant Temp. Room.	Insectary.
Egg to end of third instar (feeding stage) ..	4 days	27 days
Prepupal stage	5 days	12 days
Pupal stage	16 days	21 days
Total period from egg to adult	25 days	60 days

So marked was the effect of temperature and humidity on development that adults were present under warm, moist conditions, whilst maggots from the same batch of eggs were still feeding under normal outdoor conditions. The difference in the length of the larval stage was the most pronounced, that in the prepupal stage less so, whilst that in the pupal stage was the slightest. This was no doubt partially due to the fact that the insectary temperature was increasing as the weeks passed.

The adults also live longer and are more vigorous under warmer, moister conditions than the normal Canberra climate. Flies kept in the insectary died in a few days. Those in the constant temperature room lived from four to six weeks. A female kept in the insectary took 25 days to mature a second batch of eggs, whilst one in the warm room produced two batches within five days. In the latter case there were more than 200 eggs in each batch, and in the former there were only about 75. Moreover, the progeny of the second female had completed their life cycle in 24 days, whilst those of first took more than two months.

7. *Description of the Early Stages.*

(*a*) *The Egg.*—The egg is 2·5 mm. in length. It is creamy in colour. The shape is a long ellipse, slightly curved and narrowed and flattened at the micropylar end. In eggs which are near to hatching the young maggot can be seen shrunken away from the transparent chorion and with the pointed head towards the micropylar end.

(*b*) *First Stage Larva.*—The maggot at this stage is 4 mm. long. It is sharply pointed at the head end, and broad and truncated posteriorly. The maggot has a pseudocephalon, three thoracic, and eight normal and two very reduced abdominal segments. The head is divided, as in all blowfly larvae, into two distinct lobes, each bearing a maxillary palp and a small papillate antenna on the dorsal surface. There are two well-marked but unbranched oral grooves present. The two lateral hooks of the bucco-pharyngeal armature are strongly chitinized and conspicuous.

The anterior border of the first thoracic segment bears a row of strongly chitinized black spines which are short, stout and closely set all round the margin. They are smaller and less heavily chitinized on the dorsal surface. This segment sheathes round the head and has a slightly bilobed flap projecting forward. In this region it bears several sinuous rows of small dark spines more or less projected backwards, and becoming smaller in the more posterior rows. The second and third thoracic segments have a couple of rows of spines on the anterior borders all round, and these are more chitinized and conspicuous on the ventral surface.

Each abdominal segment also bears rows of spines on the anterior border. These widen out on the ventral median surface to several rows where they form a distinct patch behind the junction of each segment. Unlike the other segments the first abdominal segment has in place of the lozenge-shaped area two rows of spines. Towards the middle of each lozenge-shaped spiny area there is a clear space devoid of spines. This space is placed slightly posteriorly, that is, there are about five rows of spines in front of the clear space and two behind, so that it does not lie in the centre of the spiny area. The posterior rows of spines are the largest and most heavily chitinized and are directed backwards. The spiny areas project downwards making a ventral bulge on each segment.

The posterior spiracles are in the form of dorsal stigmatic plates on the eighth abdominal segment. They are very pale and seem to be hardly more chitinized than the skin of the larva. Two slits are present, which are short, wide and close together. The felt chambers are noticeable through the thin skin, and the tracheal trunks can be seen from the dorsal surface diverging as they pass inwards. There are no other spiracles present in the larva at this stage.

(*c*) *Second Stage Larva.*—The following description is from a larva ten days old. The two-lobed structure of the head and the antenna and maxillary palp are the same as in the previous stage. The lateral hooks are both the same size and bear small thin spines.

The anterior border of the three thoracic segments has very small and inconspicuous spines. Ventrally at the anterior margin each of the abdominal segments bears a wide band of rows of small spines directed backwards. They form a band right across the ventral surface instead of a median patch as in the previous stage larva. The clear space towards the centre is, however, still present.

As in the first-stage maggot the spiny bands from a lateral view appear as distinct swellings on the ventral surface of the abdominal segments. Dorsally the band is not as wide or conspicuous as on the ventral surface. It is distinguishable on the first four segments and then fades away, and is again noticeable on the last four. On the ninth segment ventrally there are two large projections, and the anus, representing the tenth segment, is situated between and a little behind these. The posterior spiracles are in a hollow on the dorsal surface of the eighth segment. The plate bears two slits which are short and wide with chitinous sinuous edges, and the outside slit has a distinct bend in the centre. The peritreme or chitinous border of the plate is very thin and inconspicuous. There are six papillae round the edge of the hollow, behind the spiracles and beneath them. These papillae form the most posterior extremity of the maggot, projecting backwards over the last two segments.

One maggot was killed and preserved just at the ecdysis between the second and third instars. The body of the maggot had shrunk away from the last two segments of the previous skin leaving it quite transparent, so that the old spiracular plates with two slits were plainly visible. The new posterior spiracular plates were seen on the new maggot through the transparent old skin. They were faint and not chitinized, being the same colour as the skin of the maggot. The three slits, however, were distinct and plainly visible.

(*d*) *Third Stage Larva.*—The following description is from a larva nineteen days old. The full-grown maggot is 16 mm. in length. The head is relatively much smaller than in the previous instars, having not increased in the same proportion as the rest of the body. The first thoracic segment overlaps the head slightly on the dorsal surface and is very spiny at this point. The anterior spiracles are conspicuous on the first segment of the thorax and are fan-like, ending in nine papillae. The general structure of the maggot is similar to those already described. The body segments are well marked, more swollen and annulated at the junctions than in previous instars. The junctions are marked by bands of spines, which are most numerous and conspicuous on the ventral surface where the band widens. The last four large abdominal segments have the junctions less swollen, especially dorsally where there is practically no annulation.

The posterior spiracles lie in a deep hollow on the dorsal surface of the eighth segment. There are six little papillae on the anterior dorsal rim of this hollow, and two outer larger and two inner smaller ones on the posterior lower margin.

Two more papillae are situated outside and below these, but also on the rim of the depression. Below this depression there is a ventral protrusion, the ninth segment, which is covered with small spines above and has the anal opening in the middle.

Spines are present around the lower edge of this also. The ninth segment bears a pair of large papillae, one on each side of the anus projecting laterally.

Posterior Spiracles.—The distance between the spiracular plates is, on an average, 0·27 mm. The general conformation and structure of the spiracles is typically Calliphorine, being very similar to that of all other Calliphoras examined. The plates are almost round in outline but slightly projecting at the button or external scar, and showing a slight scalloping or bulging where the upper end of the slit reaches the peritreme. The peritreme is strongly chitinized, but not very wide, and has inward projections between the slits. The button is completely enclosed in the peritreme.

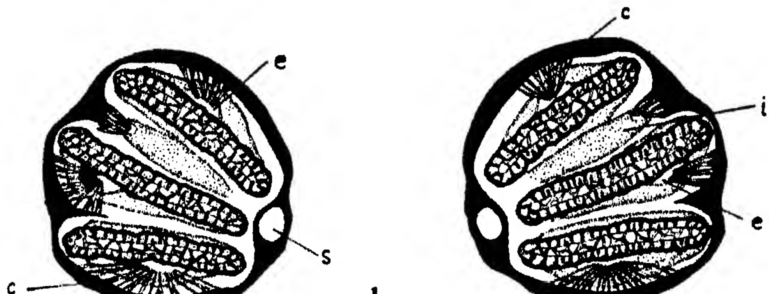
The three slits are narrow and elongated, running the full length of the plate, and making bulges in the peritreme at their upper ends. The slits are equal distances apart at their bases near the button. They diverge from here, but are still about equal distances apart at the apex near the peritreme. The lower or outer slit is a little shorter than the other two and has a slight curve upwards at the middle. The middle slit curves downwards at the centre, and the upper or inner one curves upwards. Thus there is a space between the inner and middle slits which is occupied by the "intermediate structure" of Froggatt, whilst the outer and middle slits come close together at the middle. The lower slit runs straight outwards, whilst the other two run outwards and upwards.

There are four openings of perispiracular glands. These are in the form of small round, clear spaces. One is situated on the top of the "intermediate structure", between the inner and middle slits, one is on the upper margin of the inner slit at its middle, one is on the lower margin of the middle slit towards its outer end, and the fourth is on the lower margin of the outer slit about its middle. From the openings of the perispiracular glands a series of fine, chitinous hairs radiates in a fan-shaped fashion, reaching the peritreme. In most preparations these appear as lines on the ground membrane of the spiracular plate and are referred to by Froggatt as "sun-ray effects". The slits bear thick chitinous borders which are sinuous or scalloped, leaving only a narrow cleft down the centre of the slit which is crossed by a network of chitinous bars running from one border to the other. The peritreme is paler round and near the button The inward projection of the peritreme between the middle and inner slits is often bifid, one point running each side of the perispiracular gland opening in this situation.

Some features of the spiracles are variable. There is practically no inward projection of the peritreme between the slits in some cases, and occasionally the slits do not run the full length of the plate and cause bulges in the peritreme, but end short with quite a space between their upper ends and the peritreme. The shape of the slits and other features are constant.

Anterior Spiracles.—The tracheal trunk ends in a wide felt chamber which terminates in a variable number of short papillae, from nine to eleven in most cases, but one example had only eight. They are well separated from each other, and the openings at the ends of each are large, with thick chitinous rims. The papillae spread out in a fan-like manner, and in the specimen with eight only they were farther apart and more spread out than usual. The top of the felt chamber just below the papillae has numerous large, clear spaces in it.

Buccopharyngeal Armature.—The pharyngeal sclerite is similar to that of all other Calliphorine larvae examined. There is the usual deep incision in the posterior end, and the dorsal cornua are long and have the inner edges very strongly chitinized. The ventral cornua also have the inner edges most heavily chitinized. Along the ventral margin of this sclerite runs the ribbed ventral wall of the pharynx. According to Keilin, this feature is characteristic of all Cyclorrhaphous dipterous larvae which are saprophagous. At the anterior end of the pharyngeal sclerite there is a pair of narrow chitinous rods projecting forwards from it, and with the ends hooked sharply upwards like a ladle.



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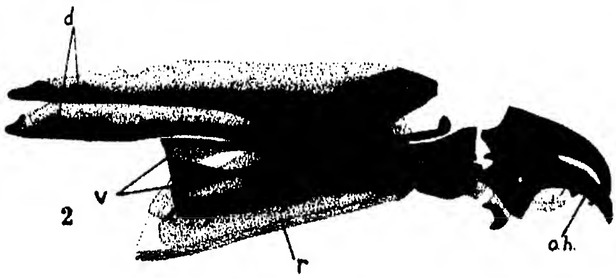

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Text-fig. 1.—Posterior spiracles of third stage larva of *C. ochracea*. × 95. *c*, chitinous hairs; *e*, external opening of perispiracular glands; *i*, "intermediate structure"; *s*, external scar.

Text-fig. 2.—Buccopharyngeal armature of third stage larva of *C. ochracea*. × 42½. *d*, dorsal cornua; *o.h.*, oral hooks; *r*, longitudinal ridges; *v*, ventral cornua.

The middle or hypopharyngeal sclerite is very heavily chitinized and articulated posteriorly with the pharyngeal sclerite and anteriorly with the base of the oral hooks. This sclerite is small, the whole armature being narrowest at this point. The oral hooks are very chitinous and black, with wide triangular bases which have a small hole in the centre. The hooks are of equal length, long and pointed. There is a short chitinous rod, wider at the posterior end, projecting forwards between the oral hooks. Ventrally, at the base of each hook there is a small thick, crescent-shaped sclerite, heavily chitinized, with the posterior horn narrowing to a tail. In the ventral curve of the hooks, projecting ventrally, there is a pair of yellowish, lightly-chitinized, curved disc-like structures, which are behind the median rod.

The maggot of *C. ochracea* is a typical *Calliphora* larva. On comparing it with the maggot of *C. stygia* they are found to be remarkably similar in detail. The only real distinction lies in the spiracles. *C. stygia* has more papillae in the anterior spiracles, usually twelve. These are longer and narrower than in *ochracea*, and the whole structure is larger and more robust. The posterior spiracles, however, offer the most reliable distinguishing characters. In *C. ochracea* the plates are almost round, and in *stygia* they are elongated at right angles to the slits, becoming broadly pyriform. Also in *stygia* they possess strong projections of the peritreme between the slits and corresponding concavities in the outline, giving a definitely scalloped, shell-like appearance. The peritreme is thicker and stronger, and the distance between the plates is greater. Moreover, the slits are wider, shorter and closer together in *stygia*.

The Puparium.—The puparium is dark-brown in colour, and 10 mm. in length. It has eleven segments marked off by a thin greyish band which represents the band of spines in the maggot. These bands have a forward curve on the ventral side and, as in the larva, they are distinctly wider on the ventral surface of the puparium. The posterior spiracular plates are the same dark-brown colour as the puparium and the three slits appear as small shiny ridges. The anterior spiracles appear as stiff, yellowish fan-shaped structures with ten fingers directed outwards and slightly backwards. They occur one on each side of the middle line of the first segment. The small papillae surrounding the hollow in which the posterior spiracles lay are still present as small hard projections. The puparium is more convex on the dorsal than the ventral side. At the posterior edge of the third thoracic segment on the dorsal surface and to the side are two tiny horn-like projections. They are also dark-brown and are directed forwards. The puparium has a slight concavity where these horns arise.

8. *Conclusion.*

An interesting feature of this work lies in the fact that *C. ochracea*, whilst very distinctive in the adult stage, is so remarkably like other Calliphoras in the earlier stages. Unfortunately, no indication has been gained of its breeding habits in nature. Although the maggots thrive in carrion under experimental conditions, they have never been found in carcases in the field, so it seems not unlikely, as the flies readily oviposit in thick fur, that they are restricted to the dead bodies of some particular native animal. Thus similarity in the larval environment to that of other Calliphoras may account for the identity of the maggots, the adult environment and habits being different from other species.

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THE GASTEROMYCETES OF AUSTRALASIA. XI.

THE PHALLALES, PART II.

By G. H. CUNNINGHAM,
Mycologist, Plant Research Station, Palmerston North, N.Z.

(Plates viii–x.)

[Read 27th May, 1931.]

This paper is a continuation of Part I of the Phallales (in which the family Phallaceae was discussed) and covers the Australian and New Zealand species included in the families Clathraceae and Claustulaceae.

Family II. CLATHRACEAE.

Peridium obovate or subglobose, at first submerged, becoming superficial or almost so; rupturing from the apex downwards to form several lobes, exposing the receptacle and persisting as a volva supporting this structure; gelatinous layer broken into plates by bands of intermediate tissue corresponding with the arms of the receptacle. Receptacle completely free within the volva, of various types, stipitate or sessile, clathrate, columnar, or of apically united, connivent or free arms arising from the apex of the stipitate base, chambered, pseudoparenchymatous. Gleba borne on the arms of the receptacle or upon some modified portion of these. Basidia bearing 4–8 sessile, elliptical, smooth, continuous spores.

The family may be separated into 3 distinct tribes, and contains the following 11 genera:

Key to the Tribes and Genera.

Tribe I. STELLATEAE: Receptacle stipitate, of simple arms borne on the apex of a simple hollow stem; arms either apically organically united, connected by a membrane, free and connivent, or laterally expanded from the discoid apex of the stem.

Arms apically organically united or united by a membrane.

Glebiferous layer composed of irregular pseudoparenchymatous processes ...... 1. (**Mycopharus*†)

Glebiferous layer consisting of walls of the chambers of the arms ...... 2. *Anthurus*.

Arms apically free, connivent or expanded.

Arms connivent (usually), attached to the apex of a simple cylindrical stem ...... 3. *Lysurus*.

Arms attached laterally to a horizontal discoid expansion of the apex of the cylindrical stem ...... 4. *Aseroe*.

Tribe II. COLUMNATEAE: Receptacle without a stipitate base, of simple columnar arms organically united apically, but free basally.

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* Genera not occurring in Australia or New Zealand are placed in brackets.

† *Mycopharus* Petch (1926, p. 281) was proposed by Petch to replace *Pharus* (Petch, 1919, p. 59) which was erected to contain "*Lysurus Gardneri*"; *Pharus* being preoccupied by a genus of the Gramineae.

Gleba attached to the inner surfaces of the columns.
  Columns transversely rugose or smooth .... 5. *Linderia*.
  Columns with lateral winged expansions .... 6. (*Blumenavia*).
Gleba attached to a pendent pulvinate structure attached to the ventral surface of the apex of the united columns .... 7. (*Laternea*).

Tribe III. CLATHRATEAE: Receptacle of arms anastomosing to form a globoid, hollow, sessile clathrate sphere, of arms clathrately arranged above, but columnar below and/or basally united to form a short cylindrical stem, or clathrate and supported upon a definite stem.
Receptacle with a definite cylindrical stem.
  Receptacle arms not lobed .... 8. (*Simblum*).
  Receptacle arms with numerous lateral capitate or clavate lobes attached exteriorly .... 9. (*Kalchbrennera*).
Receptacle clathrate above, arms below columnar and united basally to form a short cylindrical base .... 10. *Colus*.
Receptacle sessile or practically so, clathrate .... 11. *Clathrus*.

I have rearranged this family, dividing it into three tribes on account of the arrangement of the arms of the receptacle.

In the tribe Stellateae are placed the four genera *Mycopharus*, *Anthurus*, *Lysurus* and *Aseroe*, since all show a close resemblance one to another, consisting essentially of a receptacle, the base of which is a definite stipe, the apex divided into arms. In *Anthurus* (as emended below) the arms are organically united apically, in *Mycopharus* held together apically by a fine membrane, in *Lysurus* free apically but usually connivent (in occasional plants two or three of the arms may be united organically, *cf. L. sulcatus* and *L. mokusin*), and in *Aseroe* are laterally expanded and attached to the horizontal discoid apex of the stem of the receptacle. The arms of *Mycopharus* differ in the structure of the glebiferous layer from the other three genera included in the tribe, consisting of a series of thin processes or contorted plates closely compacted together.

In the tribe Columnateae I have placed the genera *Linderia*, *Blumenavia* and *Laternea*. All three possess a receptacle of simple columnar arms, apically united organically, but basally free. In *Linderia* the columns are smooth or transversely rugulose and bear the gleba on their inner surfaces; in *Blumenavia* the columns have strongly developed winged expansions, but otherwise the genus is similar to *Linderia*; and in *Laternea* the gleba is restricted to a pendent, pulvinate structure attached to the apices of the united columns.

In the tribe Clathrateae are placed the genera *Colus*, *Simblum*, *Kalchbrennera* and *Clathrus*. In all, the receptacle is composed of arms anastomosing to form a clathrate receptacle. In *Clathrus* the receptacle is clathrate throughout, and sessile, though in certain forms the lower arms tend to assume a columnar position, and occasionally are basally united to form a short tubular stem (upon this feature has been erected the genus *Clathrella*), approaching closely the genus *Colus*. This latter typically consists of a receptacle apically clathrate (that is, the arms in the upper portion anastomose to form a latticed structure), but below the arms assume a columnar position and fuse basally into a tubular flaring stem. *Simblum* has the appearance of a clathrate globoid receptacle carried at the apex of a cylindrical, hollow stem; and *Kalchbrennera* is of a similar structure, but in addition there arise exteriorly from the arms of the receptacle numerous clavate or capitate lobes. In all genera placed in the Clathrateae the arms form a closed receptacle, being united apically and basally, and this distinction is sufficient, in my opinion, to show that they are not closely related to the Columnateae.

The geographic distribution of genera of the family is interesting. *Mycopharus* is confined to Ceylon; *Blumenavia* to Brazil; *Laternea* to the West Indies;

Kalchbrennera to Africa; *Colus* is found in the Mediterranean region and Australia (possibly, too, in New Caledonia); *Simblum* in the West Indies and warmer regions of North and South America; *Linderia* in the south of North America, Hawaii, Ceylon, Japan and New Zealand; *Anthurus* in Australia, New Zealand, North and South America, Java and Ceylon; *Lysurus* in Europe, Asia, North America, Africa and Australia; *Ascroe* in Australia, New Zealand, Asia, Ceylon, India, South America and East Indies; and *Clathrus* has a world-wide distribution.

Development.

The development of *Clathrus ruber* has been worked out by Fischer (1890, p. 3). As in the Phallaceae the primordium arises from the rhizomorph as a small clavate body composed of an outer cortical and an inner medullary layer (Pl. viii, fig. 1). The medullary tissue enlarges rapidly and assumes a broadly pyriform appearance. It then becomes lobed (Pl. viii, fig. 2) and the lobes continue to enlarge unequally, being more numerous apically (where the arms in the mature receptacle are more numerous) and expand peripherally to form (ultimately) the gelatinous plates of the middle layer of the volva. Between the lobes lies undifferentiated tissue of the cortex, and as the lobes increase in size peripherally, this undifferentiated tissue becomes compressed between them to form the so-called intermediate tissue (Zwischenflecht) of Fischer (Pl. viii, figs. 1, 2, *c*). Where the lobes tend to flatten near the periphery, compression of the intermediate tissue leads to the formation of the thin peridial plates (Pl. viii, fig. 3, *e*); but towards the central part of the plant the undifferentiated cortical tissue occupies small cleft-like cavities, and in these spaces arise thickened hyphal knots, which are the fundaments of the arms of the receptacle (Pl. viii, fig. 3, *d*). These shortly become enclosed within a palisade of hyphae. The wall of the medullary tissue enclosing these clefts likewise becomes lined with palisade tissue, and between them a cavity appears, indicating the beginning of glebal formation, this being the first glebal chamber (Pl. viii, fig. 3, *f*). By radial elongation of the lobes of medullary tissue (which begin to gelatinize peripherally about this time) these cavities increase in size; the walls then become covered with hymenium, develop lateral expansions, which increase in size and number, and ultimately form the labryinth of cavities and tramal plates of the gleba (Pl. viii, fig. 5, *g*). Development continues progressively towards the centre of the plant, until the whole of the medullary tissue lying within the zone indicated by the appearance of the first glebal cavities is converted into gleba.

Where the intermediate tissues come in contact with the gleba, the hyphae grow into certain of the glebal chambers and fill them with a luxuriant growth of hyphae. This, together with the palisade surrounding the hyphal knots, is then converted into pseudoparenchyma, giving rise to the walls of the arms of the receptacle. Those portions of intermediate tissue enclosed within the pseudoparenchyma gelatinize and in this manner are formed the chambers of the arms of the receptacle.

The labyrinth of glebal tissue then produces basidia and spores, and ultimately becomes gelatinized. Gelatinization of the peripheral portions of the lobes of the medullary tissue continues until the whole of the peripheral region is converted. In this manner is formed the middle layer of the peridium, which is broken into numerous areas by the peridial plates, which correspond in number and position to the arms of the receptacle (Pl. ix, fig. 18). The exterior layer of

the peridium is derived from the but slightly differentiated cortex (Pl. viii, fig. 5, *i*), and the inner layer is bounded by the peripheral zone of the gleba and arms of the receptacle.

As the receptacle develops its walls become thrown into folds (Pl. ix, fig. 18); and at maturity, increased turgour of the arms (and possibly, too, of the now gelatinized gleba) causes rupture of the peridium (along the sutures formed by the peridial plates), the receptacle expands considerably and becomes free, the peridium remaining then as a volva at its base (Pl. x, fig. 19).

In *Linderia columnata*, according to Burt (1896), development proceeds in a similar manner, save that only a few lobes of the medullary tissue are developed, due to the simplified nature of the receptacle. In this species development of the columns of the receptacle is continuous over the apical part (leading to the arms being organically united in the mature plant) but is interrupted basally, so that at maturity the columns are free from one another.

The development of these two species differs considerably from that described for members of the Phallaceae. For in *Mutinus* and *Ithyphallus* it was shown that the cortex gave rise to the outer layer of the peridium alone, all other tissues arising from the medulla. In *Clathrus* (and *Linderia*) the cortical tissue not only produces the outer layer of the peridium, but in addition the walls of the receptacle and peridial plates of the volva. A second feature of the Clathraceae is that so far as their development has been studied critically, the gleba develops interiorly to the tissues of the receptacle, whereas in the Phallaceae it develops externally to the pileus (or modified apex of the receptacle in *Mutinus*). These differences are sufficient to maintain these two families as distinct, and tend to show, moreover (since no intermediate forms are known) that they have had a different, though probably parallel, line of evolution.

1. Anthurus Kalchbrenner.

Grev., ix, 1880, p. 2. *Emend.—Pseudocolus* Lloyd, *Myc. Notes*, 1907, p. 356.

Peridium of 3 layers, the outer furfuraceous and thin, the middle one thick and gelatinous. Receptacle a short, cylindrical or flaring, hollow stem, bearing apically a variable number (3–8) of simple, brittle arms organically united apically (though often breaking free at maturity). Gleba borne on the inner surfaces of the arms, mucilaginous, fetid, olivaceous. Spores tinted or hyaline, continuous, smooth, elliptical.

Habitat.—Growing on the ground or on decaying wood.

Type species, Anthurus Archeri (Berk.) Fisch.

Distribution.—France; North and South America; Island of Reunion; Java; Ceylon; Japan; Australia; New Zealand.

This genus is characterized by the receptacle, which consists of a hollow, cylindrical or flaring stem bearing apically several simple arms united at their apices. In one species (*A. Rothae*) the stem is often considerably reduced, sometimes not projecting beyond the volva.

The genus was erected by Kalchbrenner upon a plant from Richmond River, New South Wales. The specimen no longer exists, consequently most subsequent workers have had to attempt identification of the species (and genus) from Kalchbrenner's description and crude illustration (Pl. 3, fig. 3). The latter does not resemble any known Phalloid (see Pl. viii, fig. 7), and would appear to be a composite sketch of *Aseroe rubra* and a plant Fischer (1890, p. 67) labelled *Anthurus Muellerianus* f. *aseroeformis*, collected by Bauerlen at Quiedong, Gipps-

land. Fischer's illustration is based on a plant which McAlpine later named *A. aseroeformis.*

In 1860 Berkeley described *Lysurus Archeri* from a plant collected in South Tasmania. His description and illustration (see Pl. viii, fig. 8) show a plant resembling *A. Muellerianus* f. *aseroeformis*, but differing in that the apices of the five arms are united. Recent collections made in Australia and New Zealand have shown that Berkeley's plant is not uncommon, and that when the receptacle emerges from the peridium the arms are (usually) united apically (as his figure has shown them), but after exposure for a short time they tend to become detached (being decidedly brittle when fresh), the plant then assuming the form of Fischer's *A. Muellerianus* f. *aseroeformis.* It is obvious, therefore, that both are conditions of the same species, and that as Berkeley's name has priority, the specific name becomes *A. Archeri.*

Reference to Kalchbrenner's figure (Pl. viii, fig. 7) shows his *A. Muellerianus* to be a plant with eight free arms, attached to a short hollow stem; and as Berkeley's figure shows a plant with five united arms (Pl. viii, fig. 8), it may be thought that two different species are involved. But as in New Zealand forms with seven arms are not uncommon, it is evident *Lysurus Archeri*, *Anthurus Muellerianus*, and *A. Muellerianus* f. *aseroeformis* (= *A. aseroeformis* McAlp.) are but names for the same species.

Kalchbrenner's description of his genus *Anthurus* covers plants with "Receptacle stipitate, or with a very short stem, divided above into erect patent laciniae, free at the apices, but running down direct into the stem, and not distinct from it". And subsequent workers have had difficulty in determining the differences, if any, separating it from *Lysurus.* But as I have shown, the type species is a plant with the arms organically united apically, and that Kalchbrenner's figure refers to a weathered plant in which the arms had broken free. It is clear therefore that the concept of the genus has become changed, and that several species placed under it must be referred to *Lysurus.*

In 1907 Lloyd erected *Pseudocolus* to contain plants with arms organically united apically, and attached basally to a hollow stem; in other words to contain species placed under *Anthurus* as now defined. Thus *Pseudocolus* is but a synonym of *Anthurus.*

In the genus as emended, there are four species. Of these *Anthurus Garciae* (A. Moell.) n. comb. (= *Colus Garciae* A. Moell., *Braz. Pilz.*, 1895, p. 35) occurs only in Brazil, and differs from the others in its white receptacle; *A. javanicus* (Penz.) n. comb. (= *Colus javanicus* Penz., *Ann. Jard. bot. Buit.*, xvi, 1899, p. 160) is a red species with three arms, found in Java, Island of Reunion (as *Colus fusiformis* Fisch., 1890, p. 64), Japan (Lloyd, *Myc. Notes*, 1916, p. 586) and North America (as *Colus Schellenbergiae* Sumst., *Mycologia*, viii, 1916, p. 183); *A. Archeri* (Berk.) Fisch. is a red species with five to eight arms, and occurs in New Zealand, Australia, Tasmania, Mauritius, Malay Archipelago and France; and *A. Rothae* (Fisch.) n. comb. is confined to Australia.

1. Anthurus Archeri (Berkeley) Fischer. Pl. viii, fig. 6.

Jahrb. bot. Gart. u. Mus. Berlin, iv, 1886, p. 81.—*Lysurus Archeri* Berk., *Fl. Tas.*, ii, 1860, p. 264.—*L. pentactinus* Berk., *l.c.*, tab. 184.—*Anthurus Muellerianus* Kalch., *Grev.*, ix, 1880, p. 2.—*A. Muellerianus* f. *aseroeformis* Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxii, 1890, p. 68.—*A. aseroeformis* (Fisch.) McAlp., in Lloyd's *Myc. Notes*, 1908, p. 408.—*Pseudocolus Archeri* (Berk.) Lloyd, *Letter* 47,

1913, p. 14.—? *Anthurus MacOwani* Marl., ex Lloyd, *Myc. Notes*, 1916, p. 570.—*Pseudocolus mauritianus* Lloyd, *Myc. Notes*, 1917, p. 689.—*Anthurus surinamensis* Fisch., *Ann. Myc.*, xxv, 1927, p. 471.

Peridium obovate, to 4 cm. diameter, but usually smaller, exterior furfuraceous, dingy-white. Receptacle with a short, hollow, usually flaring stem, to 5 cm. long, but often much less, 1–2·5 cm. diameter, attenuate and white below, slightly expanded, open and red above; divided directly into 5–8 simple arms, which are red, transversely rugulose on the interior, sutured longitudinally externally, chambered, apically united (usually) when freshly expanded, but commonly breaking away in older plants, varying from 3 to 7 cm. in length, occasionally bifurcate at the extremities. Gleba borne on the inner surfaces of the arms, fetid, olivaceous. Spores hyaline, elliptical, 6–7·5 × 2–2·6 μ.

Type locality.—South Tasmania.

Distribution.—Australia; Tasmania; New Zealand; Mauritius; Malay Archipelago; ? South Africa; ? France.

Tasmania: Type locality (Berkeley, *l.c.*).—N.S.W.: Richmond River (Kalchbrenner, *l.c.*); Mt. Royal Range; Yarrowitch; Squdgy Creek, near Bulli Pass (Cleland and Cheel, 1915, p. 207).—Vic.: Quiedong, Gippsland (Fischer, *l.c.*); Upper Owens River (Fischer, *l.c.*); Melbourne (McAlpine, *l.c.*).—N.Z.: Unknown locality (Lloyd, *Letter 59*, 1915, p. 1); Peel Forest, Canterbury (Lloyd, *Letter 47*, 1913, p. 14); Cromwell, Otago, G.H.C.; Nelson, Dun Mt., G.H.C.

This is a red species somewhat uncommon in Australia and New Zealand. The arms vary in number from five to eight, plants with five arms being most frequently collected; they may be organically united, held together by a fine membrane (Cleland and Cheel, 1915, p. 207), or occasionally free, though the last two conditions are rare in freshly expanded plants; and may be entire at their apices (when broken away) or occasionally bifid. This last condition is rare and has been recorded but twice (by Berkeley, *l.c.*, and Cleland and Cheel, 1915, p. 206), and would appear to be limited to those arms which are organically free in unexpanded plants.

The variable nature of the species has led to considerable speculation as to its identity, with the result that it is found in literature under many names. As has been shown, it was first named in 1860 by Berkeley as *Lysurus Archeri* (and his illustration as *L. pentactinus*); in 1880 by Kalchbrenner as *Anthurus Muellerianus*; and by McAlpine in 1908 as *A. aseroeformis*. Then Lloyd (*Letter 47*, 1913, p. 14) recorded receipt of a specimen in which two of the six arms were united apically and concluded they were all so joined originally. The following year (*Letter 51*, 1914, p. 4) he received a coloured drawing from C. C. Brittlebank (Melbourne) showing a plant with all arms organically united apically, and accordingly renamed the species *Pseudocolus Archeri*. Then in 1917 Lloyd received from Mauritius a plant which he named *Pseudocolus mauritianus*. This had the five apically united arms and short stem of our plant and is accordingly considered to be the same species. In 1925 Lloyd (*Myc. Notes*, p. 1361) recorded the species (under the name of *Anthurus aseroeformis*) from France, and, judging from his illustration, his record would appear to be based on an authentic specimen. Finally Fischer recorded the species (as *A. surinamensis*) from Surinam, Malay Archipelago. His plant had the same five arms, red colour, short stem and organically connected arms (though some are broken apart in his illustration) and so must be regarded as the same species. I have examined three collections from Otago and Nelson and find that the number of arms varies, as

has been shown; for of the seven specimens examined, three possessed five arms, one had six, and three had seven.

2. ANTHURUS ROTHAE (Berk. ex Fischer), n. comb. (Pl. viii, fig. 9.)

Colus Rothae Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxiii, 1893, p. 23, *nom. nudum*.—*Pseudocolus Rothae* (Fisch.) Lloyd, *Phall. Aus.*, 1907, p. 19.

Peridium white or greyish, subglobose, 1·5–2 cm. diameter, externally furfuraceous. Receptacle variable in size, 3–5 mm. tall, of 3 or 4 triquetrous or quadrate arms organically united apically, basally contracted to form a short, cylindrical, hollow stem; arms cream-coloured basally, orange or orange-red above, transversely rugulose, hollow, attenuate above and slightly arched outwards. Gleba olivaceous, borne on the inner surfaces of the upper parts of the arms, mucilaginous, fetid. Spores tinted, elliptical, smooth, 3–4 × 1·5–2 μ.

Type locality.—Brisbane, Queensland.

Distribution.—Australia.

Queensland: Brisbane (Herb. Kew, Fischer, *l.c.*).—N.S.W.: Moonan Brook (Herb. Kew, Fischer, *l.c.*); Bulli Pass, 4/14, J. B. Cleland.*

This species is characterized by the three or four angular arms of the receptacle. The number of the arms varies, for out of eight specimens collected by Dr. Cleland, two had four arms, and the others had three, but in one of the latter, one arm was thicker and divided into two in its upper part. Another feature is that the stem of the receptacle is often reduced, when the plant is liable to be mistaken for a specimen of *Linderia*; but the organically united bases of the arms would show that such plants were of this species.

At Kew, according to Fischer (*l.c.*), the original collections forwarded by Bailey were labelled *Clathrus triscapus* and *Anthurus Rothae*; and a second collection from Moonan Brook labelled *Laternea triscapa*; which explains Cooke's reference (1892, p. 214) to the occurrence of *Laternea triscapa* in Australia.

2. LYSURUS Fries.

Syst. Myc., ii, 1822, p. 285.—*Aseroephallus* Lepr. et Mont., *Ann. Sci. Nat.*, ser. 3, iv, 1845, p. 360.

Peridium of 3 layers, the outer thin and furfuraceous, the middle layer thick and gelatinous. Receptacle a hollow cylindrical stem bearing apically several arms, distinct from the stem, and free apically. Gleba olivaceous, mucilaginous, fetid, borne on the surfaces of the arms. Spores elliptical, smooth, continuous.

Habitat.—Growing upon the ground.

Type species, *Lysurus mokusin* (L.) Fr.

Distribution.—Europe; Asia; North and South America; Africa; Australia.

The genus is characterized by the receptacle, which consists of a well developed cylindrical stem bearing apically a variable number of short arms which are apically free. It has regularly been confused with *Anthurus* (which is not surprising, since as that genus was originally defined there was no real difference between the two), and numerous efforts have been made to separate these two genera; as by Patouillard (1890), who attempted to define them upon the manner in which the gleba was borne on the arms. As *Lysurus mokusin* carries the gleba upon the exterior of the arms, Patouillard assumed that *Anthurus*

* Specimens marked thus are in the herbarium of Dr. J. B. Cleland, The University, Adelaide.

had the gleba borne internally on the inner surfaces of the arms, and made this the character of the two genera. Lloyd in his various papers attempted to show that *Lysurus* possessed a cylindrical, and *Anthurus* a flaring stem, and considered this to be the distinguishing feature.

Of the fifteen species which have been described, but four are valid, the others being synonyms either of these or of species of *Anthurus*. *Lysurus mokusin* (L.) Fr. has been recorded from China, Japan, Australia and California; *L. sulcatus* (Cke. et Mass.) n. comb. is known from Europe, North America and Australia; *L. cruciatus* (Lepr. et Mont.) Lloyd is based on a collection from French Guiana; and *L. Woodii* (MacOwan) Lloyd is confined to Africa.

1. Lysurus mokusin (L.) Fries.

Syst. Myc., ii, 1822, p. 286.—*Mutinus pentagonus* Bailey, *Queensland Bot. Bull.*, x, 1895, p. 35.—*Lysurus Beauvaisii* Moll., *Rev. Gen. Bot.*, xii, 1900, p. 61.—*Mutinus pentagonus* var. *Hardyi* Bailey, *Queensland Agr. Journ.*, xvi, 1906, p. 494.—*M. Hardyi* Bailey, *Comp. Cat. Queensland Pl.*, 1910, p. 747.—*Lysurus sinensis* Lloyd, *Myc. Notes*, 1917, p. 718.

Peridium subglobose, to 3 cm. diameter, white. Receptacle to 8 × 1·5 cm., stem white, fluted and 4–6 angled, hollow, coarsely chambered, acuminate below, bearing apically 4–6 arms, which are usually strongly connivent, to 25 mm. long, acuminate, rugulose, orange. Gleba olivaceous, fetid, borne on the exterior of the arms. Spores tinted, elliptical, 4–5·5 × 1·8–2·2 μ.

Type locality.—Province of Mokusin, China.

Distribution.—China; Japan; California; Australia.

Queensland: Brisbane (F. M. Bailey, Hardy, J. H. Simmonds, Bailey, *l.c.*).

The species is characterized by the strongly fluted and angled stem of the receptacle, strongly connivent arms, and by the gleba being carried on the outside of the arms.

The Australian record is based on specimens collected in Queensland by Bailey and others. These were placed under *Mutinus* and described as new, two species and one variety being erected by Bailey according to whether the stem was four, five or six angled. Bailey's illustrations show all to be forms of *L. mokusin*. Lloyd's *L. sinensis* was based on a specimen from Japan, in which two of the arms were organically united at their apices. But as this feature is not uncommon in *L. sulcatus* and *L. Woodii* it has no specific import. Lloyd (*Myc. Notes*, 1916, p. 586) recorded the occurrence of the species in a glasshouse in California, where it doubtless has been introduced accidentally with plants or soil brought from the Orient. It is possible that it has been introduced similarly from China to the north of Australia.

2. Lysurus sulcatus (Cooke and Massee), n. comb.

Lysurus texensis Ellis, *Bull. Torrey Bot. Club*, vii, 1880, p. 30, *nomen nudum.*—*Mutinus sulcatus* Cke. et Mass., *Grev.*, xvii, 1889, p. 69.—*Lysurus australiensis* Cke. et Mass., *Grev.*, xviii, 1889, p. 6.—*Anthurus australiensis* (Cke. et Mass.) Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxiii, 1893, p. 27.—*A. borealis* Burt, *Mem. Bost. Soc. Nat. Hist.*, iii, 1894, p. 504.—*Lysurus borealis* (Burt) P. Henn., *Hedw.*, xli, 1902, p. 167; var. *Klitzingii* P. Henn., *l.c.*, p. 173.—*L. tenuis* Bailey, *Comp. Cat. Queensland Pl.*, 1910, p. 745.

Peridium subglobose, white, to 3 cm. diameter. Receptacle to 15 × 2 cm., stem white below, cream-buff above, cylindrical, or acuminate below, hollow, of 1–3

layers of chambers, divided apically into 5–7 arms which are erect, hollow, narrowly lanceolate, 10–30 mm. long, apically attenuate, transversely rugulose, pallid-orange and differing in context from the stem. Gleba borne on the inner surface and edges of the arms, sometimes completely surrounding them, brownish, mucilaginous, fetid. Spores elliptical, smooth, hyaline or tinted, 4·5–5 × 1·5–2 μ.

Type locality.—Brisbane, Queensland.

Distribution.—Germany; England; North America; Australia.

Queensland: Brisbane (Cooke and Massee, *l.c.*, Bailey, *l.c.*).—N.S.W.: Killara; Penshurst; Wahroonga; Botanic Gardens, Sydney; Woolwich; Milson Island; Cronulla Beach; Campsie; Richmond; Neutral Bay (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 206); Palm Beach, Sydney, 4/18*; Byron Bay, 4/16*, J. B. Cleland.—S. Aust.: Grange, 2/24, J. B. Cleland*; same loc., 4/24, Mrs. Kelly*; same loc., 4/25, A. J. Garfield Williams*; Millswood, 6/28, J. B. Cleland*.

This appears to be one of the most abundant Phalloids in Australia, judging from the number of collections recorded. It is identical in all particulars with *L. borealis*, as I have satisfied myself after examination of numerous collections from America and Australia. This has been previously pointed out by Lloyd (1909, p. 38). It differs from *L. Woodii* only in the orange colour of the arms, those of the latter being white, according to van der Bijl (1921, p. 192). Petch has shown (1919) that *Mycopharus Gardneri* differs in the structure of the arms of the receptacle. I have examined the microscopic structure of the arms of *L. sulcatus* and find they are composed of strongly convoluted folds of pseudo-parenchyma arranged in parallel series, forming a close palisade similar to that described (in part) by Petch.

Cleland and Cheel (1915, p. 204) have shown that the number of the arms varies from five to seven; and that forms with two or more of the arms organically united apically, laterally or by a delicate membrane are not uncommon. These forms show the close relationship of the genus to *Anthurus*. The disposition of the gleba is by no means constant; for it may be spread over the whole of the arms, and is quite common on the lateral surfaces of these structures. This shows the fallacy of delimiting genera upon the disposition of the gleba alone, as has been attempted by Patouillard, Fischer and others.

3. Aseroe La Billardière.

Ex Fries, *Syst. Myc.*, ii, 1822, p. 285.—*Calathiscus* Mont., *Ann. Sci. Nat.*, ser. 2, xvi, 1841, p. 278.

Peridium of 3 layers, the outer thin and furfuraceous, the middle one thick and gelatinous. Receptacle a hollow cylindrical stem bearing apically a horizontal discoid expansion, to the margin of which are attached a variable number of horizontally arranged arms, which may be simple or bifurcate. The apex of the stem is often covered with a diaphragm, usually with a small central perforation. Gleba mucilaginous, olivaceous, fetid, imposed upon the upper surface of the disc and proximal portions of the upper surfaces of the arms. Spores smooth, continuous, elliptical.

Habitat.—Growing solitary upon the ground or on rotting wood.

Type species, Aseroe rubra Lab. ex Fr.

Distribution.—China; Japan; Ceylon; South America; East Indies; Australia; New Zealand.

The genus is characterized by the manner in which the numerous, usually awl-like arms are laterally inserted into the discoid expansion of the apex of the

stem, and presence of a diaphragm (an inward continuation of the disc) covering its apical aperture. Its relationship to *Anthurus* is indicated by occasional plants of *Anthurus Archeri* which possess apically free, shortly bifurcate and awl-like arms.

There are but three valid species in the genus, the many others described being synonyms of these. *A. arachnoidea* Fisch. is known from Cochin China and Java, and differs from the others in its white colour and the fact that the arms are inserted singly into a barely perceptible disc; *A. ceylanica* Berk. occurs in Ceylon and Tonkin and is a red species differing from *A. rubra* in the much broadened apical disc of the receptacle; and *A. rubra* Lab. ex Fr. is restricted to Australia, Tasmania, New Zealand and New Caledonia.

1. Aseroe rubra La Billardière. Plate viii, fig. 10; Pl. ix, figs. 11, 12.

Ex Fries, *Syst. Myc.*, ii, 1822, p. 285.—*A. pentactina* Endl., *Icon. Gen. Pl.*, Pl. 1, 1838.—*A. viridis* Berk. et Hook., in Hook. *Journ. Bot.*, iii, 1844, p. 192.—*Lysurus aseroeformis* Cda., *Icon. Fung.*, vi, 1854, p. 22.—*Aseroe actinobola* Cda., *l.c.*, p. 23.—*A. Hookeri* Berk. *Fl. N.Z.*, ii, 1855, p. 187.—*A. corrugata* Col., *Trans. N.Z. Inst.*, xvi, 1883, p. 362.—*A. lysuroides* Fisch., *Jahrb. bot. Gart. u. Mus. Berlin*, iv, 1886, p. 89.—*A. rubra* a. *typica* Fisch.; b. *pentactina* (Endl.) Fisch.; c. *actinobola* (Cda.) Fisch.; d. *Muelleriana* Fisch.; in Sacc. *Syll. Fung.*, vii, 1888, p. 26.—*A. Hookeri* a. *miniata* Fisch.; b. *viridis* Fisch., *l.c.*—*A. Muelleriana* (Fisch.) Lloyd, *Syn. Phall.*, 1909, p. 46.—*A. pallida* Lloyd, *l.c.*, p. 47.—*A. poculiforma* Bailey, *Comp. Cat. Queensland Pl.*, 1910, p. 746.

Peridium obovate, to 3 cm. diameter, dingy-white. Receptacle stem cylindrical or flaring, hollow, chambered, to 6 × 2 cm., white and attenuate below, pink and expanding above into a broad, horizontal, orbicular disc, to 3·5 cm. diameter, to which the arms are attached laterally. Diaphragm usually well developed, smooth or definitely rugulose, sometimes almost wanting. Arms in 5–9 pairs, conniving, to 3·5 cm. long, 6 mm. wide near the base, longitudinally grooved basally, rugose on both surfaces, but more deeply on the upper, or almost smooth, bifurcate at about 15 mm. from the base (sometimes bifurcate only near the apices), subulate towards the tips, which are often twisted. Gleba covering disc, diaphragm and upper surfaces of the lower portions of the arms, fetid, mucilaginous, olivaceous. Spores tinted, often hyaline, elliptical, smooth, 4–5·5 × 1·5–2 μ.

Type locality.—South Tasmania.

Distribution.—Tasmania; Australia; New Zealand; New Caledonia.

Tasmania: No locality (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 209; La Billardière, ex Fries, *l.c.*).—Queensland: Brisbane (Bailey, *l.c.*, as *A. poculiforma*).—N.S.W.: Byng; Peakhurst; Turramurra; Camperdown; Penshurst; Killara; Woollahra; Croydon; Parramatta; Chatswood; Lismore; Rookwood; Weston; West Maitland; North Sydney; Neutral Bay (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 212).—Victoria: East Gippsland (herb. Berlin, Fischer, 1890); Dandenong (Berk., *Journ. Linn. Soc., Bot.*, xiii, 1872, p. 170).—New Zealand: Common throughout the lowland forests of both Islands.

This is an abundant species throughout New Zealand, for I have collected it in all Provinces; and it appears to be equally abundant in East Australia and Tasmania. It is decidedly variable as to size, colour, number of arms, diameter of the discoid expansion of the stem, and degree of roughening of the disc, diaphragm and arms. Thus it is not surprising to find the species has many synonyms. *A. pentactina* Endl. was erected on a species with five bifid arms;

A. viridis Berk. et Hook. was supposed to be a metallic-green (!) colour. Later Berkeley re-named it *A. Hookeri* Berk. on account of its supposed small size. I have examined the type at Kew and find it to be identical with one of our many forms. *Lysurus aseroeformis* Cda. and *A. lysuroides* Fisch. are names for a form from Tasmania in which the stem is longer and the base of the arms broader than in the original plant. Fragments of the "type" are, according to Fischer (1890, p. 73) in herb. Delessert in Geneva. *A. corrugata* Col. differs slightly from the typical form in the surfaces of the arms being more rugulose; but this is a condition so variable as to possess no significance. *A. Muelleriana* (Fisch.) Lloyd is a form in which the disc is much broader, more roughened interiorly, and the arms shorter than in the typical form, and on this account may possibly be worthy of a varietal name (Pl. ix, fig. 13). *A. pallida* Lloyd was based on a specimen from New Caledonia with a white stem and pale-rose disc. It appears to be identical with our plant. *A. poculiforma* Bailey was based on a specimen in which the arms were less expanded than usual, a not uncommon condition where plants are growing among grass or partially buried in dead leaves and other debris on the forest floor.

The colour of the plant varies somewhat, pink or bright-scarlet forms being the most common. I have collected on two occasions (Weraroa, May, 1919, and York Bay, Sept., 1927) plants with a perfectly white receptacle, the only colour present being that of the gleba. These specimens were identical in all other respects with the red form and were found on rotting wood. The number of the pairs of arms varies from five to nine. In typical plants they are bifurcate for about three-fourths of their length, but even this condition varies, for in some specimens the arms may be bifurcate only near their extremities, or from their junction with the disc. Several may fuse together, or become twice bifurcate at their apices.

4. Linderia, n. gen.

Peridium subglobose, of 3 layers, the outer furfuraceous, the middle one thick and gelatinous. Receptacle of simple columns, organically united apically, but free and tapering basally. Columns chambered, pseudoparenchymatous, smooth or transversely wrinkled, but not winged; bearing on their upper parts of the inner surfaces the mucilaginous, olivaceous gleba. Spores elliptical, smooth, continuous.

Habitat.—Growing upon the ground.

Type species, *Clathrus columnatus* Bosc.

Distribution.—North America; West Indies; Hawaii; Japan; New Zealand.

This genus has been erected to contain those species possessing a columnar receptacle and arms organically united apically, but free basally. That this is a characteristic feature is evident when it is remembered that all genera placed in the tribe Columnateae (*Linderia*, *Laternea* and *Blumenavia*) possess this same feature.

Earlier workers have had considerable difficulty in placing species belonging to this genus, for we find them scattered equally through *Clathrus*, *Colus* or *Laternea*. Fischer (1890, p. 55), for example, considered *Laternea triscapa*, *Linderia pusilla*, *Linderia columnata* and *Clathrus ruber* to be forms of the same species. As these are valid species, belonging to three different genera, it is evident Fischer had but a scant knowledge as to the generic limits of the Clathraceae. Most subsequent workers have followed Fischer, and placed several,

if not all, of the valid species of *Linderia* under *Clathrus* or *Colus*; save Lloyd (1909), who placed them under *Laternea*.

Linder (1928, p. 109) has shown that the genus *Laternea* was erected upon a species possessing simple columns which subtend from the junction of the apices an angular, subobovate structure to which the gleba is restricted. The presence of this specialized glebiferous structure leaves those species with the gleba carried upon the inner surfaces of the columns without a generic name, and for this reason I have erected *Linderia*, in honour of David H. Linder, Mycologist to the Missouri Botanic Gardens, who has so clearly defined the characters of the genus *Laternea*. Linder suggested that Rafinesque's proposed name *Colonnaria* be used. But as Rafinesque did not describe or illustrate his genus, nor indicate a type species (his contribution (1808) being "Colonnaria (urceolata, truncata, etc.) divided into four pillars, united at the top, which bear the seeds in the margin. Found in Penn."), it is evident that it is mere guesswork to assume he was dealing with any of the species under consideration, or in fact with a fungus at all.

As defined, the genus contains the following three species: *Linderia columnata* (Bosc), n. comb.; *Linderia bicolumnata* (Lloyd), n. comb. (= *Laternea bicolumnata* Lloyd, *Myc. Notes*, 1908, p. 405); and *Linderia pusilla* (Berk. et Curt.) n. comb. (= *Laternea pusilla* Berk. et Curt., *Journ. Linn. Soc. Bot.*, x, 1869, p. 343). The distribution of the first is given below; the second is confined to Japan; and the third to Cuba.

1. Linderia columnata (Bosc.), n. comb. Plate ix, figs. 14, 15.

Clathrus columnatus Bosc., *Mag. Gesell. nat. Freunde Berlin*, v, 1811, p. 85.—*C. colonnarius* Leman, *Dict. Sci. Nat.*, ix, 1817, p. 360.—*Laternea columnata* Nees et Henry, *Syst. d. Pilze*, ii, 1858, p. 96.—*Clathrus cancellatus* c. *columnatus* Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxii, 1890, p. 56.—*Clathrus trilobatus* Cobb, *Rept. Exp. Stn. Hawaii Sugar Pl. Assn.* Bull. 5, 1906, p. 209.

Peridium subglobose, to 8 cm. diameter, rupturing irregularly from the apex downwards. Receptacle of 3–5 (commonly 3–4) columnar arms, basally free and acuminate, apically united, arched slightly outwards, chambered, transversely rugulose or papillate interiorly, longitudinally striate exteriorly, shading from pallid-orange below to ruby-red at the apex. Gleba spread over the inner surfaces of the upper portions of the arms, olivaceous, mucilaginous, strongly fetid. Spores tinted, elliptical, smooth, 3·8–6 × 1·5–2·5 μ.

Type locality.—South Carolina.

Distribution.—North and South America; West Indies; Hawaii; New Zealand.

New Zealand: Lynton Downs, Canterbury (Herb. Kew, Lloyd, *Myc. Notes*, 1906, p. 298); Kaituna, Canterbury, Miss Watson, 5/21 (Herb. Canterbury Museum).

The presence of the species in New Zealand is based on the two records cited above. The Kaituna specimen forms the subject of our illustration, and differs from typical forms of the species in the more slender, more coarsely cellular arms; but in this highly variable plant this is scarcely of specific significance. Occasionally the arms where apically united, form a flattened dome, and in extreme forms there may be present distinct perforations giving the plant a somewhat clathrate appearance (*cf.* Fischer's illustration of *Clathrus cancellatus* e. *Fayodi*, 1890, Pl. 5, f. 37; Coker and Couch, 1928, Pl. 1), and for this reason it has been included under *Clathrus* by most workers; but the free bases of the arms of the receptacle show that it is not closely related (Pl. ix, fig. 15).

5. Colus Cavalier and Sechier.

Ann. Sci. Nat., ser. 2, iii, 1835, p. 251.—*Clathrella* Fisch., *Nat. Pflanzenfam.*, i, 1900, p. 284, *pro parte*.

Peridium obovate, smooth externally, of 3 layers. Receptacle with arms anastomosing apically to support a clathrate dome, below forming several short columns which unite basally to form a hollow, flaring, tubular, stem-like base. Gleba borne on the inner surfaces of the upper portions of the arms, olivaceous, fetid, mucilaginous. Spores smooth, elliptical, continuous.

Habitat.—Growing on sandy soil or on dung.

Type species, Colus hirudinosus Cav. et Sech.

Distribution.—Southern Europe (France, Spain, Portugal); North Africa; Ceylon; Australia.

The genus is characterized by the receptacle which typically consists of a clathrate dome supported on arms arranged in columnar fashion and produced basally to form a short, cylindrical, stem-like base. Thus defined, it closely resembles certain species of *Clathrus*, especially those placed by Fischer in *Clathrella*. Notwithstanding the fact that the genus was based on a species possessing a receptacle of the type described, numerous workers have referred to it plants which belong to *Anthurus*, *Mycopharus*, or *Clathrus*. The following is the only species usually recognized (which really belongs to the genus), but as is shown under *Clathrus*, it is possible other species exist.

1. Colus hirudinosus Cav. et Sech. Pl. ix, fig. 17.

Clathrus hirudinosus Tul., *Expl. Sci. Alg.*, 1849, p. 435.

Peridium obovate, to 2·5 cm. diameter, white or dingy-grey externally. Receptacle to 6 cm. tall, apically sparsely clathrate, centrally of 5–7 (or in rare cases more) slender columnar arms united basally into a short cylindrical stem. Arms angled, transversely rugulose, red above, orange below. Gleba olivaceous, borne on the inner surfaces of the arms of the upper portion of the receptacle, fetid. Spores tinted, elliptical, smooth, 5–6 × 1·5–2·2 μ.

Type locality.—Toulon, France.

Distribution.—Southern Europe; North Africa; Australia.

N.S.W.: Milson Island, Hawkesbury River, 3/16, J. B. Cleland*; Byron Bay, 4/16, J. B. Cleland*.

The collections made by Dr. Cleland are exactly as the plant was figured by Tulasne (*l.c.*) as our figure (based on a water-colour in the possession of Dr. Cleland) shows; but differs from the photograph of specimens from Portugal published by Lloyd in being less clathrate and the stem-like base less developed. Cooke (1892, p. 215) recorded the species from Western Australia and illustrated it with a copy of Tulasne's figure (Pl. 23); but according to Fischer (1890, p. 63) this record was based on a plant he (Fischer) named *Colus Muelleri*, which is in my opinion merely a specimen of *Clathrus pusillus* with a rudimentary stem-like base.

5. Clathrus Micheli.

Ex Persoon, *Syn. Meth. Fung.*, 1801, p. 241.—*Clathrus*§*Clethria* Fr., *Syst. Myc.*, ii, 1822, p. 287.—*Ileodictyon* Tul., *Ann. Sci. Nat.*, ser. 3, ii, 1844, p. 114.—*Clathrella* Fisch., *Nat. Pflanzenfam.*, i, 1900, p. 284, *pro parte*.

Peridium globose or obovate, exterior thin and furfuraceous, middle layer thick and gelatinous. Receptacle of several arms organically united to form a

hollow latticed sphere; sometimes arms arranged in columnar fashion below, and in extreme forms prolonged into a short cylindrical stem-like base; arms smooth or rugulose, in section elliptical, angled or rounded, cellular or tubular. Gleba borne on the inner surfaces of the arms, mucilaginous, olivaceous, fetid. Spores elliptical, smooth.

Habitat.—On the ground or on decaying wood.

Type species. Clathrus ruber Mich. ex Pers.

Distribution.—World-wide.

The genus, as defined above, contains plants in which the arms are organically anastomosed to form a clathrate spherical receptacle. In several species there occur forms with the lower arms arranged in columnar fashion, and projected basally to form a short, hollow, stem-like base. These last closely approach *Colus*, and indeed have led Fischer and others to a misinterpretation of the latter genus. For they have referred to *Colus* plants placed by myself under *Anthurus*, or by Lloyd under *Pseudocolus*. And to make the position more confusing, Fischer erected *Clathrella* to contain these intermediate forms.

Anthurus contains species in which the simple arms are borne on a distinct stem, and apically organically united; *Colus* possesses a flaring stem bearing apically a few columnar arms which apically branch and anastomose to form a clathrate dome (*cf.* the type species); if these points are borne in mind, little confusion should arise, and it will become apparent moreover that *Clathrella* is untenable.

Many workers have also confused *Linderia* (as *Colus* or *Laternea*) with *Clathrus* but this confusion cannot arise if it is remembered that in *Linderia* the bases of the arms are free, whereas in *Clathrus* they are organically united.

Tulasne erected *Ileodictyon* to contain those species with tubular arms, as opposed to the cellular arms of such species as *Clathrus ruber*. But as the type of his genus (*C. cibarius*) contains plants which are either tubular or coarsely chambered (small specimens being tubular, large ones chambered) this distinction cannot be considered as of generic value.

There would appear to be ten valid species in the genus (*Clathrus delicatus* Berk. et Br. being in my opinion a *Colus*) which can be divided into sections according to the colour of the receptacle, cellular or tubular nature and degree of roughening of the arms. Of the red species *C. crispus* Turp. occurs in the West Indies, and North and South America; *C. crispatus* Thwaites is confined to Ceylon; *C. ruber* Mich. ex Pers. is common in Europe, southern North America, South America and North Africa; *C. pusillus* Berk. is confined to Australia; and *C. Treubii* (Bern.) Lloyd to Java. Of the white species *C. Preussii* (Fisch.) Lloyd is known from a single collection from East Africa; *C. chrysomycelinus* A. Moell. is confined to Brazil; *C. gracilis* (Berk.) Schlecht. is confined to Australia; and *C. cibarius* (Tul.) Fisch. to Australia and New Zealand. Lastly *C. camerunensis* P. Henn., recorded from Africa, is said to differ in possessing an olivaceous receptacle, which seems improbable.

1. Clathrus cibarius (Tulasne) Fischer. Pl. ix, fig. 18; Pl. x, figs. 19, 20.

Jahrb. bot. Gart. u. Mus. Berlin, iv, 1886, p. 74.—*Ileodictyon cibarium* Tul., *Ann. Sci. Nat.*, ser. 3, ii, 1844, p. 114.—*Clathrus Tepperianus* Ludw., *Bot. Centralbl.*, xliii, 1890, p. 7.—*Ileodictyon giganteum* Col., *Trans. N.Z. Inst.*, xxv, 1892, p. 324.—*Clathrus Higginsii* Bailey, *Queensland Ag. Jour.*, xxix, 1912, p. 487.

Peridium obovate or subglobose, dingy-white, to 7 cm. diameter. Receptacle sessile, white, subglobose or commonly obovate, to 15 × 10 cm., composed of numerous obliquely anastomosing arms, which are transversely rugulose, in section elliptical, tubular or more often coarsely cellular, not or scarcely thickened at the interstices (though in some forms attaining a thickness twice that of the arms). Gleba covering the inner surfaces of the arms, olivaceous, mucilaginous, fetid. Spores tinted, elliptical, smooth, 4–6 × 1·8–2·5 μ.

Type locality.—Waitakei, Otago, New Zealand.

Distribution.—New Zealand; Australia.

N.S.W.: Arncliffe; Gladesville; Yarrangobilly (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 216).—South Australia: Blackwood, 7/30, E. Ashby*.—New Zealand: Common throughout the lowland areas of both Islands.

This is the only *Clathrus* known to occur with certainty from New Zealand, where it is exceedingly common in certain seasons, being found in spring and autumn on the edges of forest clearings, or freshly-turned earth at roadsides or tracks cut through the forest. It occurs sparingly in Australia, but its distribution is not certainly known since the species has been confused by earlier workers with the following one. Fischer recorded it from Chile, West Africa (1890, p. 53) and East Africa (1893, p. 19). I believe, however, that the species is confined to this biologic region, and that Fischer has confused it with plants later named *C. Preussii*, *C. chrysomycelinus* or *C. camerunensis*.

The receptacle varies greatly in size (5–15 cm.) and in the number and arrangement of the arms. In many plants the arms are numerous, and form a close mesh, in which the polygonal interspaces are small; in others the arms may be few and the meshes large and angular. The arms may anastomose in such a regular manner that in plants detached from the volva it is not possible to determine the apex from the base; or in others the arms towards the base may be arranged in columnar fashion, or in rare cases produced to form a small basal tube-like stem. The surfaces of the arms may be smooth, finely transversely wrinkled, or exteriorly longitudinally grooved. In section they may be tubular or coarsely cellular, both conditions being not infrequent in the same plant.

The receptacle is not attached to the volva in any way, consequently it may be readily detached and carried by wind for some distance from its place of origin. The appearance of these latticed structures without visible means of attachment to the substratum was a potent source of mystification to the Maori. Forced to find some explanation of their (to him) mysterious appearance, and guided no doubt by their characteristic odour he came to the conclusion (according to Mr. Elsdon Best) that they were *tutae kehua* or *tutae whetu* ("Faeces of ghosts or of the stars"). The specific name (cibarius = edible) was applied to the species under the impression that the unexpanded plant was used as an article of food by the Maori. But this is improbable as it is scarcely likely he would meddle with a plant obviously (to him) of supernatural origin. This view is supported by Mr. Best, who has advised me that the plant was not included among those fungi considered edible by the Maori.

2. CLATHRUS GRACILIS (Berkeley) Schlechtendal.

Linnaea, xxxi, 1862, p. 166.—*Ileodictyon gracile* Berk., in Hook. *Lond. Journ. Bot.*, iv, 1845, p. 69.—*Clathrus albidus* Lothar ex Fisch., in Sacc. *Syll. Fung.*, vii, 1888, p. 20. *C. intermedius* Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxiii, 1893, p. 20.

Receptacle white, sessile, variable in size and shape, 4–20 cm. diameter, arms smooth, often longitudinally sulcate externally, in section flattened, to 5 mm. thick, tubular, or with 2 or more tubes welded, expanded at the interstices. Gleba borne on the inner surfaces of the arms, olivaceous, fetid, mucilaginous. Spores hyaline or tinted, elliptical, smooth, 4·5–6 × 1·8–2·5 μ.

Type locality.—Swan River, Western Australia.

Distribution.—Australia; Tasmania.

Western Australia: Swan River (Berkeley, *l.c.*). Perth, W. M. Carne, 7/26.—South Australia: Barossa Range (Fischer, 1893, p. 19); Greenhill Road, 7/22, J. B. Cleland*; Mt. Charles, Charleston, 7/30, J.B.C.*; Adelaide, 6/23, M. Bailey*; Salisbury*; Kinchina, 7/23, J.B.C.*; Encounter Bay, 5/28, J.B.C.*; Kalangadoo, 5/28, J.B.C.*; Monash, 7/22, H. G. Taylor*.—N.S.W.: Richmond River (Fischer, *l.c.*, as *C. intermedius*); Sydney Botanic Gardens; Centennial Park; Botany; Mosman; Manly; Artarmon; Roseville; Cheltenham; Concord; Rookwood; Parramatta; Milson Island; Jerilderie; Armidale; Gostwyck, Uralla; Geeron, Forbes; Clareval, Stroud; Ingleburn; Springbrook; Deepwater; Moss Vale (Nat. Herb., Sydney, Cleland and Cheel, 1915, p. 217); Sydney, 6/15, J. B. Cleland*; National Park, 7/16, J.B.C.*; Wahroonga, 7/16, W. B. Stokes*.—Victoria: Melbourne (Fischer, 1890, p. 53).—Tasmania: Penginte (Nat. Herb. Sydney, Cleland and Cheel, 1915, p. 217).

This is somewhat similar to *C. cibarius* as to size and colour, but is quite a distinct plant, though the differences are difficult to define; and for this reason it was considered as a synonym by Fischer (1890, p. 53). In typical plants the arms are much thinner, are smooth (invariably rugulose or wrinkled in *C. cibarius*), flattened and composed of one or two (rarely more) continuous tubes. Another feature is that glebal development is frequently so copious as to coat the whole surface of the arms with the sage-green spore mass. In dried plants the arms usually assume the appearance of very fine and narrow ribbons, often only 1 mm. or so in diameter, and are characteristic on this account. It is the most abundant species in Australia, but does not occur in New Zealand.

3. Clathrus pusillus Berkeley. Plate x, fig. 21.

In Hook. *Lond. Journ. Bot.*, iv, 1845, p. 67.—*Colus Muelleri* Fisch., *Denskr. Schweiz. nat. Gesell.*, xxxii, 1890, p. 61.—*Clathrella pusilla* (Berk.) Fisch., *Nat. Pflanzenfam.*, i, 1900, p. 284.—*Simblum Muelleri* (Fisch.) Lloyd, *Syn. Phall.*, 1909, p. 64.

Peridium obovate, to 20 mm. diameter. Receptacle red, obovate, to 4 cm. diameter, clathrate, the arms somewhat columnar below, sometimes united into a stem-like base, or in certain forms clathrate above and below, columnar equatorially; arms transversely rugulose, exteriorly longitudinally sulcate, tubular. Gleba borne on the inner surfaces of the arms, fetid, olivaceous, mucilaginous. Spores hyaline, elliptical, smooth, 4·5–5·5 × 1·5–2·2 μ.

Type locality.—Swan River, Western Australia.

Distribution.—Australia.

Western Australia: Swan River (Berkeley, *l.c.*); Gilgering (Cleland and Cheel, 1915, p. 215, in Nat. Herb. Sydney); Tammin, 10/26, W. M. Carne.—Queensland: Wide Bay (Berkeley, *Journ. Linn. Soc.*, xiii, 1873, p. 172); Burnett District (Herb. Brit. Mus., Fischer, 1893, p. 22).—N.S.W.: Swanbrook; Milson Island (Cleland and Cheel, 1915, p. 215); Byron Bay, 4/16, J. B. Cleland*.—

Victoria: Upper Murray River (Fischer, *l.c.*, as *Colus Muelleri*); Gippsland (Fischer, 1893, p. 22).

This small red species appears to be not uncommon, and fairly widely though scantily distributed. Fischer (1890, p. 54) recorded the species from New Caledonia, basing his record upon a specimen in the herbarium Mus. Nat. Paris, which Patouillard (*Bull. Soc. Myc. Fr.*, iii, 1887, p. 173) referred to *Colus hirudinosus*; so that its geographic range (if this record is authentic) includes New Caledonia.

The plant may be truly clathrate, or the basal arms may be arranged below in columnar fashion; and in one collection (Upper Murray River) these columnar arms are produced into a short tubular base. This extreme form has been named *Colus Muelleri* by Fischer, and *Simblum Muelleri* by Lloyd, which well illustrates the danger of erecting species upon single specimens.

Doubtful and Excluded Species.

a.—*Clathrus crispus* Turp.—This was recorded from Rockingham Bay, Queensland, by Berkeley (*Journ. Linn. Soc.*, xiii, 1873, p. 172), but from his description I should say that this was a misdetermination of *C. pusillus*; and this is supported by the fact that *C. crispus* has not been recorded subsequently or elsewhere from this region.

b.—*Clathrus ruber* Mich. ex Pers.—Fischer (1893, p. 25) stated that at Kew there is a specimen of this species from New Zealand collected by Colenso. This Lloyd (*Myc. Notes*, 1906, p. 296) claimed to be *C. cibarius*, which is probable, for there is no other record of a red species of the genus being present in the Dominion. It may be *Linderia columnata*, for it will be remembered that Fischer confused the two species.

Family III. CLAUSTULACEAE, n. fam.

Peridium of 2 layers, the inner layer thick, gelatinous and forming a continuous layer, peridial plates being absent. Receptacle a hollow, indehiscent sphere, wall chambered and pseudoparenchymatous. Gleba covering the interior of the receptacle wall, confined to a single layer of glebal chambers, mucilaginous matrix wanting. Spores continuous, smooth, elliptical.

This family has been erected to contain the solitary genus *Claustula*. The presence of the typical peridium (although only 2-layered) and chambered receptacle shows it to belong to the Phallales; but the indehiscent receptacle, absence of the mucilaginous matrix and fetid odour of the gleba show it differs sufficiently from the Phallaceae and Clathraceae to warrant the erection of an additional family.

1. CLAUSTULA Curtis.

Ann. Bot., xl, 1926, p. 476.

Peridium of 2 layers, the outer thin and furfuraceous, the inner thick, gelatinous and without peridial plates. Receptacle obovate or subglobose, indehiscent, hollow; wall chambered, pseudoparenchymatous, gleba forming a thin layer over the inner wall of the receptacle, non-mucilaginous and without the characteristic odour of other members of the order.

Habitat.—Growing upon the ground.

Type species, Claustula Fischeri Curtis.

Distribution.—New Zealand.

1. Claustula Fischeri Curtis.

Peridium obovate, to 4·5 cm. diameter, furfuraceous, white, becoming reddish-brown, rupturing from the apex to form 4–5 acuminate lobes. Receptacle obovate or subglobose, to 5 cm. long, white, smooth, indehiscent, free within the volva; wall chambered. Gleba borne on the inner wall of the receptacle, inodorous, non-mucilaginous. Spores olivaceous, elliptical, smooth, 8–13 × 5–6 μ, shortly pedicellate.

Type locality.—Fringe Hill, Nelson, N.Z.

Distribution.—New Zealand.

Nelson: Fringe Hill, 500 m., 8/23, Miss K. M. Curtis; same loc. 7/27, G.H.C.; Dun Mt. Track, 2/28, G.H.C.

This interesting plant may be best likened to an egg (the receptacle) held in an egg cup (the volva). The volva is of the typical Phalloid type, with an outer furfuraceous and an inner thick and gelatinous layer; but differs in that the third layer is wanting, the gelatinous layer ending abruptly in a smooth surface. The receptacle is egg-shaped, hollow, of the usual chambered pseudoparenchyma, and apparently indehiscent. The gleba is produced within a single layer of lenticular cells, attached to the inner wall of the receptacle. It differs from that of the typical Phalloids in being practically non-mucilaginous and inodorous. The spores, too, are much larger than is usual in this order, and are provided with a short persistent pedicel. One additional interesting feature is that in the immature plant a thin strand of primordial tissue connects the base of the peridium with the inner tissue of the receptacle through a narrow pore at the base of the latter.

The absence of peridial plates in the gelatinous layer of the peridium shows that the affinities of this plant are more with the Phallaceae than the Clathraceae; but the development of the gleba interiorly to the tissue of the receptacle shows relationships with the Clathraceae.

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EXPLANATION OF PLATES VIII-X.

Plate viii.

Fig. 1.—Development of *Clathrus ruber*. × 12.—Longitudinal section showing medullary tissue forming the central columella of the primordium (*a*); the cortical tissue (*b*); and "intermediate tissue" (*c*).

Fig. 2.—Same at a later stage. × 12.—Longitudinal section showing commencement of development of lobes of medullary tissue. Commencement of hyphal knots is shown at (*d*).

Fig. 3.—Same, showing commencement of development of hyphal knots which later give rise to the pseudoparenchyma of the receptacle (*d*); peridial plates shown at (*e*); first glebal chamber at (*f*). × 12.

Fig. 4.—Same, showing development of glebal chambers (*f*); and tramal plates (*g*). × 12.

Fig. 5.—Cross section of the same species showing further development of tramal plates (*g*) which now form the labyrinth of the gleba; receptacle arms (*d*); peridial plates (*e*); mesoperidium now clearly defined (*h*); and exoperidium indicated at (*i*). × 12.

(Figures 1-5 after Fischer, 1890.)

Fig. 6.—*Anthurus Archeri*. × [illegible].—Photograph of a water colour drawing by C. C. Brittlebank showing the five organically united arms of the receptacle and the short flaring stem.

Fig. 7.—*Anthurus Archeri*. × $\frac{1}{2}$.—Reproduction of Kalchbrenner's drawing of *A. "Muellerianus"*. (After Kalchbrenner, 1880.)

Fig. 8.—*Anthurus Archeri*. × $\frac{1}{2}$.—Reproduction of Berkeley's drawing of *"Lysurus Archeri"*. (After Berkeley, 1860).

Fig. 9.—*Anthurus Rothae*. × [illegible].—Photograph of a water-colour drawing by Miss Phyllis Clarke in the possession of Dr. Cleland. Plant collected at Katoomba, 12/16.

Fig. 10.—*Aseroe rubra*. × [illegible].—Small 7-armed form after emergence from the volva. (Photograph by the author.)

Plate ix.

Fig. 11.—*Aseroe rubra*. × [illegible].—Fully expanded 8-armed form. (Photograph by the author.)

Fig. 12.—*Aseroe rubra*. × [illegible].—Section through the unexpanded plant showing the compressed stem, manner in which the arms are folded, massive gleba, thick gelatinous layer of the peridium, and the distinct peridial plates. (Photograph by the author.)

Fig. 13.—*Aseroe rubra*. × [illegible].—The form known as *A. Muellerianus*, showing the greatly enlarged apex of the stem and the short arms. Photograph of a water-colour by Miss Phyllis Clarke in the possession of Dr. Cleland, based on a plant collected at Mosman, 5/16.

Fig. 14.—*Linderia columnata*. × [illegible].—Photograph of a water colour by E. H. Atkinson based on a specimen collected at Kaituna, Canterbury.

Fig. 15.—*Linderia columnata*. × [illegible].—Photograph showing the free bases of the columnar arms of the receptacle. (After Linder, 1928.)

Fig. 16.—*Laternea triscapa*. × [illegible].—Photograph showing the specialized glebiferous structure characterizing the genus. (After Linder, 1928.)

Fig. 17.—*Colus hirudinosus*. × [illegible].—Photograph of a water colour by Miss Phyllis Clarke in the possession of Dr. Cleland, based on a plant collected at Milson Island, 3/16.

Fig. 18.—*Clathrus cibarius*. × [illegible].—Section through an unexpanded plant showing the strongly convoluted receptacle, the enclosing peridium and marked peridial plates. (Photograph by E. B. Levy.)

Plate x.

Fig. 19.—*Clathrus cibarius*. Natural size. A partially expanded plant showing the strongly convoluted receptacle. (Photograph by E. B. Levy.)

Fig. 20.—*Clathrus cibarius*. × $\frac{1}{2}$.—A fully expanded plant showing (in this instance) two receptacles arising from the common volva. (Photograph by E. B. Levy.)

Fig. 21.—*Clathrus pusillus*. Natural size.—A form with an exaggerated stem-like base upon which Fischer based *Colus Muelleri*. (After Fischer, 1890.)

A NOTE ON THE SYSTEMATIC POSITION OF *MYCOBACTERIUM COELIACUM*.

By H. L. JENSEN.
Macleay Bacteriologist to the Society.

(One Text-figure.)

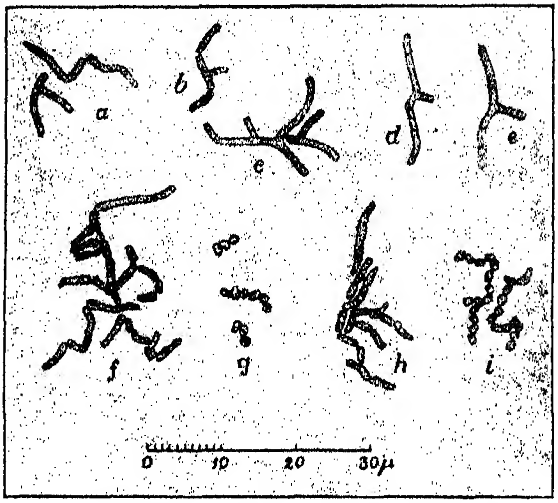
[Read 27th May, 1931.]

Mycobacterium coeliacum was described by Gray and Thornton (1928) in a study of soil bacteria capable of decomposing aromatic compounds. Twenty-five species, belonging to seven genera, were described; among these were six species of *Mycobacterium*. The authors point out that their classification is merely temporary, since our present knowledge is insufficient to enable us to classify the bacteria satisfactorily. In the most recent edition of Bergey's Manual of Determinative Bacteriology (1930) the mycobacteria described by Gray and Thornton have been transferred to other genera—five to the genus *Actinomyces*, and one, *Myc. coeliacum*, to the genus *Flavobacterium*. When the writer, in March, 1931, received cultures of some of the mycobacteria of Gray and Thornton (kindly submitted by Dr. H. G. Thornton and Mr. H. Nicol, Rothamsted Experimental Station) for comparison with a number of similar organisms isolated from Australian soils, an opportunity was found of studying the morphology of *Myc. coeliacum* a little more closely, in order to see whether Bergey's transfer of the organism to a genus of a different family and order (according to Bergey's own system of classification) is justifiable on morphological grounds.

In spite of several years of artificial cultivation the organism was still true to the characters mentioned by Gray and Thornton (1928). On ordinary nutrient agar + 1% dextrose it produces an abundant growth at 22–25° C.,* with smooth, raised, shining surface, undulate margin, first white, later pale pinkish-buff. In gelatin stab the growth is very thin; surface growth yellowish, zonate, with many lobes and secondary colonies along edge; no liquefaction. On synthetic media (dextrose-asparagine-agar and saccharose-nitrate-agar) the growth is similar to that on nutrient agar, but less abundant, with more rugose surface and of drier consistency. Microscopically the organism appears in quite young cultures (20–24 hours) as bent and curved rods, often in V-shaped arrangement, 2–6 × 0·8–1·0 μ. After two days and in older cultures one sees mostly quite short rods and cocci, 0·8–1·2 × 1·0–1·8 μ. The organism is gram positive. Gray and Thornton state

* Bergey's statement: "Optimum temperature 30° to 35° C." is incorrect. Gray and Thornton give the optimum temperature as below 30° C., and in agreement herewith the present strain grew scantily or not at all, according to the medium, at 35° C. The same is true of Bergey's statement: "Aerobic facultative". Gray and Thornton do not say anything concerning this point, but the present strain is obligate and strictly aerobic. No growth takes place in oxygen-free atmosphere, and in shake-culture on dextrose-nutrient-agar no growth is visible below a depth of about 2 mm.

that it is not acid-fast by the Ziehl–Neelsen method. The present strain showed a slight degree of acid-fastness in 20–24 hours old culture on dextrose-nutrient-agar, but not in two days old cultures or on synthetic media. In milk-culture the coccoid forms were fairly acid-fast after three days, although much less than *Myc. tuberculosis* or *M. phlei*.



Text-fig. 1.—Growth of *Myc. coeliacum* on agar, observed directly under the microscope. *a–d*, dextrose-asparagine-agar, 12 hours. *e*, same specimen as *d*, observed two hours later; septa have been formed, and the bottom cell is degenerating. *f*, same medium, 20 hours. *g*, same medium, 48 hours. *h*, water-agar, 20 hours. *i*, the same medium, 48 hours. Magnification: × 1000.

The mode of growth and reproduction of the organism was studied on three different agar media: (1) rich, complex medium: ordinary meat extract-peptone-agar + 1% dextrose, (2) synthetic medium: 1% dextrose, 0·1% asparagine, 0·1% K_2HPO_4, 1·5% agar, and (3) starvation medium: 2% agar in tap water. Cell material from a young culture on medium 2 was smeared out on the surface of sterile agar in petri dishes, and at various intervals of time small blocks of agar were cut out and examined under immersion lenses. The usual convenient method of hanging agar block culture could not be used for continuous observation of the growth, because the development of the cells soon came to a stand-still under the coverslip. The course of development was in all essentials the same on the three media (see Text-fig. 1). After 11–13 hours at 22–24° C., the cells of the inoculum have grown out into fairly long rods and filaments, up to 18–20 μ, showing true branching, occasionally to such an extent as to form small mycelia (Fig. 1, *c*, *d*, *e*). Already at this stage there is a formation of septa, resulting in cell division, and the daughter-cells occupy frequently an angular position (Fig. 1, *a*, *b*, *e*). After 18–20 hours the process of cell-division has gone so far that nearly all evidence of branching has disappeared, and the young colonies appear as composed of irregular, uneven-sided rods, about 1 μ thick and of varying length, mostly 3–8, up to 13 μ long, arranged in a characteristic angular manner and

adjoining each other at the corners, resembling diphtheria bacilli; like these, they also sometimes show parallel arrangement (Fig. 1, *f*). In some cases the young cells are seen "slipping" past each other like tubercle bacilli (Fig. 1, *h*). After two days the long rods have divided further into short rods and cocci, generally showing the same arrangement as the long rods previously (Fig. 1, *g*, *i*); this is best seen on medium 3, where only a very thin growth is produced. The life-cycle of *Myc. coeliacum* does thus, so far studied, and under the present conditions, comprise the following three main forms:

1. Long, branched rods, sometimes approaching a mycelial type.
2. Unbranched, irregular rods of medium length, resembling diphtheroids.
3. Short rods and cocci.

The figure of the growth after 12-24 hours is quite like that described for *Myc. tuberculosis* (Miehe, 1909; Gardner, 1929), saprophytic mycobacteria (Ørskov, 1923; Haag, 1927), and diphtheroids (Graham-Smith, 1910; Ørskov, 1923; Haag, 1927). Both the "snapping" type of growth of the corynebacteria (termed "angular growth" by Ørskov) and the subsequent "slipping" growth of the mycobacteria are seen here, and the occasional formation of what resembles a small mycelium has its parallels in both *Myc. tuberculosis* (Miehe, 1909) and *Myc. phlei* (Ørskov, 1923). Further, the evidence of acid-fastness under certain conditions points towards the genus *Mycobacterium*, although this character is shared to some extent by certain corynebacteria (Haag, 1927). All this speaks definitely against the classification of the organism with the genus *Flavobacterium*; moreover, the yellow pigment which should characterize this genus, is not typical here. Whether it should be termed *Mycobacterium* or *Corynebacterium* may be disputable, and this question cannot be answered satisfactorily until we possess more information concerning the complete life history of these organisms. For the present there seems to be no serious objection to the classification adopted by Gray and Thornton.

Summary.

A study of the morphology of *Myc. coeliacum* showed that this organism agrees morphologically with the genera *Mycobacterium* and *Corynebacterium*. The suggested transfer of it to the genus *Flavobacterium* cannot, therefore, be regarded as justified.

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THREE NEW BATS OF THE GENERA *PTEROPUS*, *NYCTIMENE*, AND *CHAEREPHON* FROM MELANESIA.

By Ellis Le G. Troughton, Zoologist, Australian Museum.

[Read 24th June, 1931.]*

During 1928 a very interesting collection of fishes and mammals was received from Mr. H. Ian Hogbin, from Ongtong Java, Lord Howe's Group, where he was engaged in anthropological research. As the single fruit-bat seemed hardly mature, Mr. Hogbin supplied the name of Mr. T. B. Walton, a resident of the Group, who very kindly took charge of a collecting can and returned it with three adults and a juvenile. Thanks to these joint efforts I am able to describe a new species of *Pteropus*, providing the first record of the genus in this Group.

The specimen of tube-nosed bat described herein was presented to the Museum by the Reverend Actaeon Forrest in July, 1892, associated with some other bats and fishes, from the Santa Cruz Group. This apparently new form considerably extends the range of the genus *Nyctimene*, not hitherto recorded southward of Guadalcanar Island in the Solomons.

The third species described is an insectivorous bat of the wrinkle-lipped genus, *Chaerephon*, and constitutes the first record of the occurrence of the Family Molossidae in the Solomons. An excellent series of more than a hundred specimens of this species was included in a fine collection of bats received from Mr. N. S. Heffernan, Honorary Correspondent of the Museum, while he was stationed as District Officer at Ysabel Island. For this opportunity, provided by his keen work as a voluntary collector, my sincere thanks are gratefully recorded.

Pteropus howensis, n. sp.

Diagnosis.—Of the *Pt. hypomelanus* group and apparently intermediate between *Pt. admiralitatum* and *colonus*. Though most dimensions accord well with those of *admiralitatum*, the individual teeth are heavier and the colour is very much lighter, approaching that of the true *hypomelanus*, and fur of back is much shorter than in the former; the dimensions are decidedly smaller than those of the nearest race of the latter. The forearm is considerably larger than the range given for *colonus* which, however, has a proportionately larger skull, but smaller teeth. Forearm, two adult females, 118-122 mm. Habitat: Lord Howe's Group (Ongtong Java).

Colour.—Back in the adult female holotype and paratype ranging from auburn (Ridgway, 1912), through dark-auburn to a dark-vandyke shade of brown on the rump, intermingled with a soft pencilling of buffy-white hairs. Mantle ranging from deep olive-buff with a cinnamon tinge at the nape in a young male and the palest female (paratype); in the darker holotype female the mantle ranges from cinnamon to dark-clay colour with a lighter, more buffy, hind edge. Fur of mantle strongly bicoloured; a dark mummy-brown basally. Head of holotype not markedly

* By permission of the Trustees of the Australian Museum.

contrasting with back, the light mantle colour only extending on to the head as an intermingling with the general vandyke or prout's brown tone; the cheeks, sides of neck, and throat ranging from deep-auburn to dark vandyke-brown. In the female and young male paratypes the head contrasts strongly with the back owing to the extension of the olive-buffy tone of the mantle to between the eyes, where it also mingles with the pale-vandyke shade of the cheeks.

Undersurface: In the holotype, ranging from prout's to dark prout's; though too dark for vandyke-brown, there is a distinct tone of it present, especially on the sides; and a sprinkling of silvery-buff hairs in the centre of the belly. Undersurface of the female paratype much lighter, the chest and upper parts of belly being heavily tipped with a pale shade of deep olive-buff, becoming more buffy posteriorly; the sides are clear light prout's to vandyke, lacking the pale tipping of the centre. The undersurface of the immature male agrees with this paler female, but its back and mantle are of a decidedly paler more buffy tone than in the adult females. In the paler paratypes a broad washing of the mantle colour extends across the undersurface, contrasting with the dark throat and merging into the pale tipping of the chest; in the darker holotype there is only a narrow band of paler tips, about 15 mm. broad, contrasting with both throat and chest.

External characters.—Forearms of adult females (paratype with young) 118–122 mm., as opposed to 118–126 in four adults of both sexes of *admiralitatum*; proportionately the digital dimensions average slightly longer, notably in specimens of similar forearm-length. The second digit metacarpal is 64–66·5 against 60–63·5, and the fourth digit metacarpal 81–81·5 against 75·5–81. Tibia naked above and below, though the fur which extends along the interfemoral for about half the tibia-length, as in *Pt. hypomelanus*, encroaches sparsely on to the inner third of the tibia. Fur of back adpressed and from 8 to 11 mm. long, much shorter than in *admiralitatum* (16–18), and even rather short compared with *hypomelanus* (10–14). Ears short and broad, though slightly narrower than in the former, the outer margin slightly concave below the tip, which reaches between half and two-thirds the distance to the eye, when laid forward.

Skull and teeth.—The skull proportionately somewhat narrower though general dimensions much as in *admiralitatum*, the orbital diameter smaller (11·2–3 against 12–12·5), and mandible proportionately shorter, its length 43·2–7 against 45–46·7. Individual teeth decidedly heavier than in *admiralitatum*; p^3 (maximum) 4·3 × 3·2 against 4·1 × 3, p^4 4·4 × 3·5 against 4·1 × 3·1, and p_4 4·6 × 3·2 against 4·2 × 3.

Palate ridges.—No trace of the extra ridge between the normal 9th and 10th. The 8th showing a slight variation from the *hypomelanus* description in terminating behind instead of at m^1, though not extending backwards to the marked degree of succeeding ridges.

Dimensions of holotype.—In spirit: Forearm 122; 3rd digit, metacarpal 82·5, 1st phalanx 61, 2nd 85·5; ear, from orifice 21, width 14·5; tibia 53; foot c.u., 37 mm.

Skull: Total length to gnathion 55; palation to incisive foramina 26; width, braincase at zygomata 19·7; zygomatic width 29·2; constriction, interorbital 7·2, postorbital 7·3; orbital diameter 11·2; mandible, length 43·2, coronoid height 19·4; upper teeth, c–m^2 (crowns) 21·3; lower, c–m_3 23·6 mm.

Specimens examined.—The holotype female No. M.4408, female paratype M.4824, and two juvenile male paratypes M.4825–6, in the Australian Museum, collected and presented by Messrs. H. I. Hogbin, B.Sc., and T. B. Walton.

Range.—Ongtong Java, Lord Howe's Group, Melanesia. Native name "He pe ia", supplied by Mr. Hogbin.

Remarks.—From recent observations of the British Museum series described by Andersen, there is no doubt that this form is distinctly lighter in colour than *admiralitatum*. According to my notes, the latter are actually darker than his description suggests, and therefore more in accord with the statement that their colour approaches the north Polynesian species of the *Pt. mariannus* group. Apart from the difference of colour, *howensis* is differentiated from *admiralitatum* by the much shorter hair of the back, and relatively broader and heavier teeth; from *colonus* by the longer forearm range and from the nearest races of *hypomelanus*, by the much smaller dimensions.

The much smaller dimensions distinguish it from the nearest local races of *hypomelanus*, the cranial and external measurements being actually much smaller than in *Pt. hypomelanus enganus* which averages according to Andersen "in every respect smaller than any other known race of the species"; teeth averaging about equal, but width occasionally greater than in the larger skulled *enganus*. The comparatively greater width of the teeth in *howensis* is indicated by the width of m^1, p_4 and m_1 equalling the width of these much longer teeth in *hypomelanus canus* and *lepidus*, whose teeth average the largest for the species.

NYCTIMENE SANCTACRUCIS, n. sp.

Diagnosis.—Allied to *N. scitulus* but differing in that the female holotype is quite as dark as the males of that species, instead of being of a lighter, creamy-brown, tone as in the females of the allied *scitulus* and *geminus*. Second phalanges of the 3rd and 4th digits considerably shorter than the range shown for *scitulus*, and the ear definitely smaller. The skull appears to be relatively shorter and the rostrum proportionately longer, the orbital diameter larger, and the teeth heavier. Forearm, damaged, approximately 75 mm. Habitat: Santa Cruz Group.

Colour.—Back of the female holotype quite as dark as in males of *scitulus*, the tone being mottled wood and buffy-brown with a washing of cinnamon drab; the general effect is buffy-brown rather than the purplish shade of the "brownish drab" of Andersen's description. The definite narrow spinal stripe is a shade of mummy-brown rather than the seal-brown described for *scitulus*. Undersurface much as in the description of females of *scitulus*, but the buffy-isabella tone is restricted to the sides of the neck, chest, and upper belly; the sides of body and the lower belly being buffy-brown tinged with wood-brown.

External characters.—Second phalanges of 3rd and 4th digits shorter than the range of *scitulus*, 46·5 against 52–58·5, and 31·5 to a minimum of 32 mm., in a specimen with a much smaller forearm. Ear smaller, 11·5 × 8·3 against 13–14 × 10–11·5.

Skull and teeth.—The rostrum relatively longer, and dimensions of skull wider in proportion to length than in *scitulus*, excepting the interorbital width which is 6·3 against 6·6–6·8. Orbital diameter decidedly larger, 9·2 against 8·7–8·8. Coronoid height equalling that of a much longer skull of *scitulus*, as do the general dimensions of the teeth.

Dimensions of holotype.—Dried skin: Forearm, approximately, 75; 3rd digit, metacarpal 53, 1st phalanx 41·5, 2nd 46·5; ear, from orifice (wet) 11·5, width 8·3; tibia 25; foot c.u., about 17 mm.

Skull: Length from lambda to gnathion 34·5; palation to incisive foramina 14; rostrum, orbit to nares, 7·5; width of braincase at zygomata 14; across crowns of m^1–m^1 externally 11·1; lachrymal width 9·9; across crowns of canines externally 7·4; premaxillae, depth at symphysis, 2·7; constriction, interorbital 6·3, postorbital

5·8; orbital diameter 9·2; mandible, length from condyle 28·2, coronoid height 18·4. Upper teeth, c-m¹ (crowns) 12·9; lower, c-m_3 14·2 mm.

Specimen examined.—The holotype dried female, No. M.711 in the Australian Museum collection. Presented by the Reverend Actaeon Forrest in July, 1892.

Range.—The Santa Cruz Group, Melanesia.

Remarks.—Though the actual locality was not recorded, the distance, about 350 miles, between the Santa Cruz Group and Guadalcanar in the Solomons, the nearest known habitat for the genus, appears to preclude the possibility of casual migration, or likelihood of error by the donor in recording the habitat.

The available specimens of *scitulus* appear to be decidedly darker than described by Andersen; therefore as my holotype female agrees with the darkest males of *scitulus*, instead of being much lighter as in females of that species, coloration alone would seem to differentiate the two forms, apart from the additional diagnostic features given. The fact that the female is as dark as Solomon Group males is a further indication of isolation from the species of that area, as is the fact that the Santa Cruz specimen was accompanied by two species of insectivorous bats which are identical with forms secured by Mr. A. A. Livingstone and myself during our visit to the Santa Cruz Group.

CHAEREPHON SOLOMONIS, n. sp.

Diagnosis.—Intermediate in size between *Ch. luzonus* and *plicatus*; the forearm-length the same as in *luzonus*, but the teeth, skull, and head and body dimensions decidedly larger, and also lacking the almost pure-white throat and lower belly described for *luzonus*.

General colour of similar but much richer tone, the forearm much shorter, 40·5–45 against 48·5–50, and the skull, teeth, and general dimensions decidedly smaller than in *plicatus colonicus*, the nearest ally.

External characters.—Ear similar in outline but noticeably smaller and thicker, and the antitragus narrower and shorter than in *plicatus colonicus*. Tragus broadened at the top, which is divided into anterior and posterior lobes, more or less pronounced according to the degree of concavity; in females the tragus is definitely smaller and less concave above, the upper outline therefore less markedly bilobate. Tragus thus differing from that of *plicatus colonicus*, in which the more broadly wedge-shaped tragus has a straight or slightly convex upper profile, which is never indented to form lobes. Fur of back closer, shorter, and more rigid than in *plicatus colonicus*.

Colour.—Back an even shade of auburn prout's brown which is clearer and brighter than the fuscous-tipped prout's of *plicatus colonicus*; sprinkled with occasional white hairs. Undersurface darker than in the allied subspecies, washed with dull-bistre instead of the paler wood-brown of that form.

Palate-ridges.—The hindmost ridge is never double except in its outer third, where it bifurcates to isolate a small depression opposite the antero-internal corner of m², thus differing from *plicatus colonicus* in which the posterior ridge is double throughout its length. There exist, therefore, excluding a very faint inter-canine one, but four ridges in *solomonis*, opposed to five in *plicatus colonicus*.

Skull and teeth.—Skull similar in general appearance but decidedly smaller than in *plicatus colonicus*, and the upper profile much more sinuate, the convexity in outline and development of the sagittal crest in the forepart of the braincase being much more pronounced. This greater development of the sagittal crest apparently also serves to distinguish it from the true *plicatus* which according to

Dimensions of *Chaerephon luzonus*, *solomonis*, and *plicatus colonicus*.

	Ch. luzonus. Holotype ♂. Luzon, Philippines.	*Ch. solomonis*, n. sp.				*Ch. plicatus colonicus*	
		Holotype ♂. M.3606.	Allotype ♀. M.3636.	200 specimens.		Adult ♂. Burketown, North-west Queensland.	Holotype ♂. Alexandria, North Australia.
				M.3632. Minimum ♂.	M.3627. Maximum ♂.		
Forearm	44·4	44·2	44	40·5	45	49·5	50
Head and body	54	67	68	63	68	72·5	67
Tail	33	36·5	35	35	36	40·5	42
Third digit, metacarpal..		43·5	43·5	40	45	49·5	50
Third digit, first phalanx		17·8	17·2	16·8	18	19·3	21
Third digit, second phalanx		16·8	17	15·5	17	19·4	22
Third digit, third phalanx		7·2	7	6·5	7	9	
Fifth digit, metacarpal..		25	24	23	25	29	
Ear, length from back of head		12·5	12·5	12·7	12·5	15	
Ear, length from base of antitragus ..		19·5	18·8	19·2	20·5	20·5	22
Ear, greatest width		16·5	16·5	14·5	16·5	18	
Lower leg..		14·5	14	13·5	15·5	19	18
Foot c.u...	10	8·9	8·9	8·5	9	9·5	
Skull.							
Greatest length	17·6	19·2	18·6	17·9	19	21	
Length to occipital crest		19	18·3	18	18·8	21·5	22
Condylobasal length	16·2	17·7	17	16·6	17·5	19·5	
Basal length		15·8	15	14·7	15·6	17·8	17·7
Zygomatic width..	10	11·5	10·5	10·6	11		13·5
Mastoid width	9·6	10·8	10·2	10·3	10·5	11·5	12
Palatal length		7·7	7·3	7·2	7·7	8·9	
Interorbital constriction	3·1	4	3·9	3·8	3·9	4·5	
Mandible length	11·8	13·3	13	12·8	13·2	14·6	
Teeth, c–m^3	6	7	6·7	6·7	7	8	8
Teeth, c–m_3		7·6	7·1	7·3	7·6	8·8	9
Teeth, mandibular row, entire	7	8	7·6	7·8	8	9·3	

Thomas has less developed crests than his subspecies. Greatest length of skull 18·6–19·2, intermediate between *luzonus* (17·6)) and *plicatus colonicus* (21 mm.). Teeth, c-m^3 (6·7–7), also definitely intermediate between *luzonus* (6) and *colonicus* (7·7–8).

Measurements.—For detailed measurements of typical and paratypical series, and allied forms, see table on page 208.

Specimens examined.—Holotype male No. M.3606, allotype M.3645, and a series of more than 200 paratypes.

Collected and presented by N. S. Heffernan Esq., late Deputy Commissioner for the Western Pacific Government.

Range.—Ysabel Island in the Solomons. Collected in a cave at Mufu Point, six miles west of Tuarugu Village, south-west coast of Ysabel.

Remarks.—The following notes were supplied by the donor: "Called at Mufu Point and climbed up to caves and obtained a sackfull of bats. All of one kind, and there does not appear to be any other. Proportion of males to females, 1-6. Attempted photo of the swarm at sunset, estimated to be a mile in length and 50 yards broad before dispersing, but too dark and the film a blank. It is interesting to note that Mufu Point caves have absolutely only the one kind of bat, whereas a cave only a few miles distant has five varieties and probably more, but the situations are entirely different. Mufu Caves open out onto sheer cliffs over the water. The other cave is right on top of a hill in dense forest, and about 600 feet above sea-level."

Regarding generic characters, it is fortunate that Oldfield Thomas (*Journ. Bombay Nat. Hist. Soc.*, xxii, 1, 1913, pp. 89-91) provided features other than the closed premaxillae to differentiate *Chaerephon* and its allies since, as he remarked, "all sorts of intergradations are found in the premaxillae" so that it is often almost impossible to decide the generic identity of an individual by this character. My own experience, in clearing nine crania, was that a slip of the prosectorial knife, even under binoculars, could readily remove the frail traces of the junction, and the palatal branches isolating the two minute foramina.

In his description of *plicatus colonicus*, Thomas stated that examples of *plicatus* from New Guinea and Fiji corresponded in size with Javan and Indian specimens. As the life-size drawing of Buchanan-Hamilton's type of the true *plicatus* makes the forearm 48·5 mm., and Dobson records 49·5 for the forearm of an adult male, there seems no doubt that the longer forearm distinguishes it from *solomonis*. The colour is also evidently much brighter than in the true *plicatus*, described as "above bluish or smoke-black, beneath somewhat paler" by Dobson. It has already been shown that the size of the forearm, skull, and teeth, and, to a somewhat lesser extent, the colour and character of the fur, clearly differentiate *solomonis* from the Australian form of *plicatus*.

NOTES ON THE BIOLOGY AND MORPHOLOGY OF THE *EURYMELINAE* (CICADELLOIDEA, HOMOPTERA).

By J. W. Evans, M.A., F.E.S.,
Division of Economic Entomology, Council for Scientific and Industrial Research.

(Plate xi; nineteen Text-figures.)

(*Communicated by Dr. R. J. Tillyard.*)

[Read 24th June, 1931.]

Introduction.

The Eurymelinae, which comprises a group of insects entirely confined to Australia and the neighbouring islands, has up to the present time been regarded as a division of the Bythoscopidae, owing to the facial position of the ocelli, though it differs from true members of that family in possessing broad flap-like subgenital plates with apical spine-like styles, quite distinct from the narrow plates found in the Bythoscopidae. In fact China (1926) considers that the group merits elevation to family rank.

The insects which form the subject of this paper belong to the Eurymelini division of the Eurymelinae; they may be distinguished from the other division of the group, the Pogonoscopini, by the following characters. In the Eurymelinae the hind tibiae are quadrilateral in section and have distinct spur-like teeth, with mobile spines at their apices, while in the Pogonoscopini the hind tibiae are rounded in section with the outer sides flattened, and bear a regular armature of spines arising direct from the tibiae themselves.

The first description to be published of an insect belonging to this tribe appeared in 1825 (Le Pelletier and Serville, 1825) and from that date to the present day descriptions of new species have appeared from time to time in the scientific periodicals of other countries. No great interest appears to have been taken in the group by Australian entomologists, the first mention of it in Australia being made in 1906 by Froggatt (1906, p. 355) who made the justifiable error of considering them to be members of the family Cercopidae.

Since the types are scattered and some of the descriptions hardly worthy of the name, at the moment great difficulty attends the identification of any but the commonest species. Although neglected by entomologists in this country, these insects are by no means rare, being found principally on small eucalyptus trees in open country, and as the coloration of many of the group is bold, and they are usually found in fairly large numbers together, their observation and collection is a comparatively simple matter.

This paper is offered as a preliminary to further studies, which I hope to carry out in the future on the biology and morphology of this and related groups of insects.

Life-History.

The habits of the different species are uniform, and since it has been found impossible, owing to lack of time and opportunities, to trace through the detailed

life-cycle of any one species, a composite account has been built up, the species concerned being named in every case. The observations recorded have all been made in the neighbourhood of Canberra.

Oviposition.—Oviposition takes place principally in October and November, the eggs being laid in parallel slits made in the bark of young branches of eucalyptus trees. The manner in which the slits, or nests, of the different species are sealed varies considerably. Although a number of types have been found, it so far has been possible to discover the identity of only two of the species concerned.

The nests of *Eurymeloides pulchra* Sign. are cut in rows parallel to the axes of small branches, the twigs chosen usually being from five to ten millimetres in diameter. Each nest is covered by a narrow band of a hardened frothy secretion. Nests of *Eurymela distincta* Sign. are even better protected, since here the hardened froth is extended to form large flaps, each one overlapping the adjacent flap. In Plate xi, figure 1, are shown the nests cut by an unidentified species.

Probably every species is confined to one or a few host-plants, but so far the records are too scanty to pronounce with any certainty on this point. However, the author has only found *Eurymela rubrovittata* A.S. on *Eucalyptus melliodora*; *Eurymeloides pulchra* on *E. Blakeleyi*, and *Eurymela distincta* on *E. Bridgesiana*. Trees belonging to the genus *Eucalyptus* are not the only host-plants, nymphs of two as yet undetermined species having been found in numbers on Casuarina trees, and probably further collecting would even further increase the list.

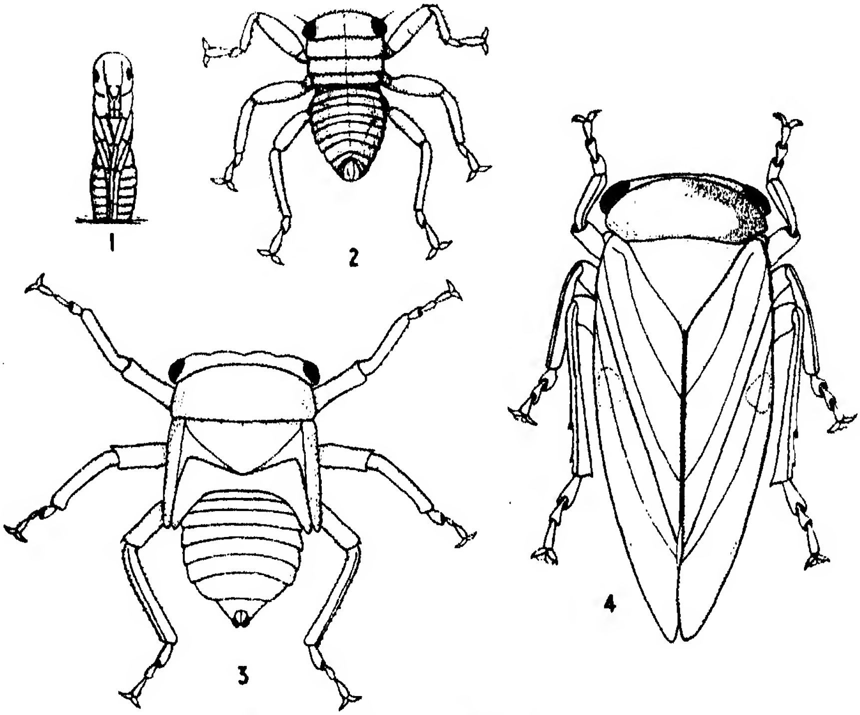
Hatching.—The act of emergence from the nests has been observed only with *E. distincta* and an unidentified species. The lower half of each egg is enclosed by a sheath constructed by the female when ovipositing. The eggs, of which about twelve are contained in a nest, are white in colour, long, and slightly curved, those of *E. distincta* being two millimetres in length. At first they are rounded at their anterior ends, but prior to hatching this end becomes pointed and contains a hard white waxy substance which gradually increases in size and density. This plug protects the delicate pronymph, and is used as a ram for pushing through the plant tissue, since the eggs are deeply embedded in the bark. When the anterior third of the egg has emerged from the bark the plug breaks up into a yellowish fluid, and the head of the pronymph appears beneath the chorion, which then splits. If an egg is dissected out of the plant, and the white plug is removed, the head of the pronymph, which contains a pulsatile sac, at once protrudes.

The pronymphs, which are colourless but for their red eyes, rise out of their nest with a lunging motion, and when about three-quarters emerged, split their skins anteriorly, so that the nymphal heads appear (Plate xi, figs. 2 and 3). These begin to swell at once, and in a short space of time the nymphs free themselves from their exuviae. Though colourless at first, they turn completely black in less than fifteen minutes, and then at once begin to feed. It is doubtful whether the whole complement of a row of eggs ever gives rise to nymphs, since the first pronymphs to leave a nest invariably crush their less pushing, and consequently less successful, neighbours.

Nymphal Instars.—The nymphs may be found abundantly during the months of November, December and January. They are gregarious at all stages, but especially during the early ones, when they congregate at the base of the season's growth of eucalyptus branches, and in the axils and along the stems of neighbouring young leaves (Plate xi, fig. 4).

They stand with their legs spread out to their full extent, their bodies being closely pressed to the plant. If disturbed, they dodge round the branch, so as to

put it between them and the intruder, and if again molested run off at great speed up or down the branch, eventually returning to where their companions are feeding together. They then push their way in among the other nymphs, until they discover a bare bit of branch in which to insert their stylets. They never jump when disturbed, their legs being adapted for clinging, not leaping.



Text-fig. 1.—*Eurymela distincta* Sign., pronymph.
Text-fig. 2.—*E. distincta*, nymph, first instar.
Text-fig. 3.—*E. distincta*, nymph, fifth instar.
Text-fig. 4.—*E. distincta*, adult.

There are five nymphal instars, exclusive of the pronymph. The adult coloration appears, as far as *E. distincta* is concerned, in the second instar. The first instar nymphs of this species are spider-like creatures, entirely black, but for the eyes, which are red, and the ventral surface of the abdomen, which is white. Nymphs in the second instar are not so squat but more elongate, and have red abdomens, similar to the adults. In the middle of each sternite at this stage and in the following three instars, is a grey area dotted with six to eight pits, presumably of a sensory nature. These do not occur in the final instar.

Later Life-History.—In the Federal Capital Territory there is probably only one complete generation a year of *E. distincta* and *E. rubrovittata*. Some of the smaller forms, such as *Eurymeloides bicincta* Erichson, have two generations, the eggs that give rise to the second one being laid in February. First instar nymphs of *E. pulchra* have been found as late as April, but doubtless they are killed by the

early frosts. During the summer the adults congregate on the trees on which they have spent their youth, but in the autumn a number migrate to new surroundings. Adults of both sexes of *E. distincta* and *E. pulchra* have been found in April resting on the sides of buildings away from any possible source of artificial light, and quite five hundred yards from the nearest eucalyptus trees. During May many have been collected on windows, attracted there by the light, but by the end of this month all the surviving adults have stopped feeding and gone into hibernation under the bark of trees, although a few will emerge from their concealment on a particularly warm sunny day during the winter.

In September and October mating takes place. This is preceded by a lengthy courtship, which has been observed between individuals of *E. rubrovittata*. A male sits astride a female, grasping her just in front of the anterior edges of her forewings with his middle pair of legs. With his fore tarsi he taps her head with light touches, and with his hind legs strokes her wings, every now and then vibrating excitedly both pairs of legs. The males are frequently anxious to mate before the females are receptive, so that the courtships are often unproductive of results.

The females continue to oviposit over a long period, and during this time it is doubtful whether they leave the tree, or even branch, first selected for the reception of their eggs. It is not known how often mating takes place, but every female, whether actually ovipositing or resting between bouts of arduous labour, waiting for her next batch of eggs to mature, is accompanied by a single male. Often many isolated colonies are found on one tree, consisting of a pair of adults and numerous nymphs.

Adults of some species retain the gregarious habits found throughout the tribe during the nymphal stages. Large colonies of *E. distincta* have frequently been found sitting along a branch, and, if one is disturbed, it will first move round to the other side of the branch, and then, if again approached, will leap away, taking to flight when in mid-air. Generally they do not fly far, but wheel round and return direct to the same tree.

Feeding Habits.—Although the nymphs feed only on tender shoots, the adults are able to obtain nourishment from more woody tissue. When a nymph commences to feed, its whole body is moved rhythmically up and down, the abdomen being bent slightly forwards and downwards, and the thorax pushed forwards, as if to force the mandibles into the plant tissue, the whole weight of the body being used for this purpose. A third instar nymph of *E. pulchra* has been observed almost to pivot on its proboscis whilst feeding, first the hind two pairs and then one fore leg being raised, and the whole body twisted with a forceful screwing movement.

Adam White (1845), in a paper describing a "New Genus and some new species of Homopterous insects from the East", gives the following note about the feeding habits of these insects: "With reference to the genus *Eurymela* I may mention that Mr. Harrington of Bath informed me that in New Holland the different species are named 'manna-flies'. They bore into the green bark of the gum trees (Eucalypti), the sap exudes, dries and falls to the ground, sometimes in great quantities. This gum-tree 'manna' is sweet to the taste."

Probably Mr. Harrington confused certain Psyllidae with the Eurymelinae, since "manna" is not produced through the agency of the latter group, but by Psyllids of the subfamily Aphalarinae. Froggatt (1906, p. 364) remarks that insects of the genus *Spondyliaspis* form "sugar lerp scales", which often encrust

the foliage of young gum trees, and are sometimes so abundant that the blacks used to collect it in quantities and have a regular manna harvest.

Relationship with Ants.

Colonies are invariably attended by ants, which feed on the "honey-dew" ejected from the anal aperture. This is nothing more than the excrement and not the secretion of any special gland. A great quantity of this "honey-dew" is produced, and since this is very sticky, the young nymphs would probably get caught in it were it not for the services of the ants.

In captivity, ants have frequently been seen trying to carry off nymphs of *E. pulchra* that had fallen on their backs. The results of their efforts were usually merely to put the nymphs on their legs again, whereupon the ants lost interest in them. On one occasion an ant was seen carrying a last instar nymph of *E. rubrovittata* down a tree trunk. When captured, it immediately dropped its prey which was found to be unharmed.

It is interesting to conjecture whether the even more intimate relationship of ants with the Pogonoscopini, which are confined to Western Australia, may not have arisen in some such way, the nymphs being taken from the branches and transferred to the trunk of the same tree beneath the soil. Mr. D. C. Swan, of the Department of Biology of the University of Western Australia, forwarded to the writer in September, 1930, some specimens of *Pogonoscopus myrmex* China, taken in the nest of *Camponotus testaceipes* Sm., built against the trunk of a eucalyptus tree (*E. redunca*, var. *elata*). Mr. Swan, in a letter accompanying the insects, mentioned that the nest which consisted of tunnelling amongst loose bark at the base of the tree, contained all stages of the insect, living quite freely with the ants. Also that *E. redunca* has a smooth clean bark without any great development of cork, and it would seem that the Pogonoscopids sucked up sap from it just below ground level. Mr. J. Clark, of the National Museum, Melbourne, has observed that when insects of this tribe are attended by species of *Iridomyrmex* they are nearly always found on the shoots of plants, very rarely in the ants' nests, excepting with *I. nitidus* Mayr. The following species of ants have been found attending *Eurymela* colonies round Canberra: *Iridomyrmex detectus* Smith, *I. rufoniger* Lowne, *I. nitidus* Mayr, and *Dolichoderus* (*Hypoclinea*) *scabridus* Roger.

Natural Enemies.

Although it has been stated earlier in this paper that these insects are not rare, yet considering the abundance of their food-plants, their distribution is localized, and no doubt their numbers fluctuate greatly from year to year, due to the control effected by their numerous parasites.

In December, 1930, in the neighbourhood of the Entomological Laboratory at Canberra, a branch of an *E. Bridgesiana* tree was found badly scarred by the egg-slits of *Eurymela distincta*, the incisions extending over a length of sixteen inches. The scarred part of the branch varied in diameter from thirteen to five millimetres. There were thirty-four rows of slits cut all along one side of the branch; each row was made up of from one to fourteen nests, the average distance between the nests being six millimetres. The branch was green, but the areas round the nest had turned brown. Every nest was examined, and it was found that very few eggs were unparasitized. The majority had turned brown, and contained on an average five small hymenopterous pupae, while others

were black and contained one pupa each of somewhat larger parasites. Altogether three species of Chalcidae were bred from these eggs.

In some of the nests, more than half of the eggs had been eaten by the larvae of *Oscinosoma luteohirta* Mall. (Diptera, Chloropidae). The pupae of these flies were also found in the nests; they were very flattened owing to lack of space, and it is difficult to imagine how the flies contrive to emerge from their position under the bark.

During January, 1931, a second instar nymph of an unidentified species was found with a Dryinid larva attached to its thorax. The host was quite active, although the parasite was bulky, being fully half the size of the former. On three occasions parasitic larvae have been found in the abdominal cavities of *E. distincta*. These were shown to entomologists with a wide experience of dipterous and hymenopterous larvae, who were not able to assign them with any certainty to any Order.

Both adults and full-grown nymphs of *E. distincta* have occasionally been found with flattened white sacs lying along the sides of their bodies, these being completely hidden by the wings of the adult hoppers, and partly concealed by the wing-cases of the nymphs (Text-fig. 8). The sacs contained very flat lepidopterous larvae, lying with their heads towards the posterior ends of their hosts. At first it was considered that the sacs were cocoons, which they certainly resembled, but when a female adult hopper bearing two sacs, one on each side of its thorax and abdomen, was confined in a breeding cage, next day the sacs were empty, containing only cast larval skins, the larvae being discovered wandering about the cage. These were peculiar little objects, oval in shape, with the dorsal surface red. Each segment bore a projecting white flap, having four spines on the under surface. Inwards from these flaps, on the ventral surface, were sclerites, the pleurae, each of which bore a group of six spines. The larvae were able to move with great rapidity, due to the fact that the claws on the fore legs were modified to form adhesive pads. Unfortunately both larvae died without pupating.

Although no moths have been bred out, it may be assumed that the larvae belong to the family Epipyropidae, the larvae of which have been recorded as being parasitic on Homoptera in many parts of the world. Without further data available, it is difficult to determine the exact relationship between parasite and host. Perkins (1905) considered that it was probable that the larvae fed on the "honey-dew" produced by the Homopteron, and not on the waxy secretion as was thought by many of the earlier writers. The same author mentions that Koebele, from observations made at Sydney, believed that the hoppers died soon after the parasites quitted them, and he himself noticed that in some cases, at least with *Agamopsyche* at Cairns, death followed quickly on the withdrawal of the full-fed caterpillar. Even immediately after this event in specimens of a Delphacid, a collapse or distortion of the dorsal sclerites of the abdomen was obvious, and healthy hoppers included in the same jars as parasitized ones outlived the latter.

It is possible that the cocoon-like sacs serve to protect the larvae from being molested by ants, and are analogous with those made by Psychid larvae, which half emerge from their cases when feeding, but dart back at the slightest alarm, and since the aperture of the sacs is close to the anal opening of their hosts, it may be presumed that they feed on "honey-dew". Although the insect already referred to, which bore a parasitic larva on each side of its thorax and abdomen,

died the same day as that on which the larvae left it, yet frequently adults have been taken in the field with empty sacs attached to them, which appeared to be equally as vigorous as their unburdened companions. It is doubtful whether predators take any toll of the nymphs, since ants resent any interference with their charges, and fiercely attack an intruder.

Comparison with Membracidae.

The Eurymelinae have very different habits from those of the majority of the Cicadelloidea, though they are somewhat similar in this respect to the Membracidae. The following characteristics of the last-named family, given by Funkhouser (1923), would equally well apply to the Eurymelinae:

(i) They are principally tree and shrub inhabiting insects.

(ii) They are found most often on plants growing in open country, not in shady woods.

(iii) The adults of many species have the habit of arranging themselves in rows on the branches of trees.

(iv) The nymphs are usually found pressed tightly in the axil of a leaf, or a crotch of a twig.

(v) Some species are definitely gregarious.

(vi) If approached, an insect will often move round to the opposite side of the twig or stem, and make no attempt to fly, except as a last resort to enable it to escape.

(vii) They invariably return to the same host from which they have been disturbed.

(viii) A large number of species are attended by ants, the latter insects collecting the so-called "honey-dew", excreted from the anus of both nymphal and adult forms.

(ix) The eggs are laid in incisions made in the bark of young stems.

Although it is not suggested that these common characteristics indicate any very close degree of relationship, yet they are probably due to more than mere chance convergence, being possibly primitive characters retained by members of both groups.

Economic Importance.

These insects cannot be considered of any economic importance. Occasionally tender young eucalyptus shoots are found that have wilted, due to the feeding of numerous nymphs at their base, and it is possible that the scars on twigs, made by the females when ovipositing, might sometimes cause the death of the injured twig. However, now that eucalyptus trees have been spread by man all over the world, it is not inconceivable that these Homoptera, if accidentally introduced into other countries, and freed from their parasites, might become pests of some importance.

External Morphology.

The coloration of some of the members of the tribe is very striking. The eyes may be black, orange or red; the pronotum and scutellum totally black, or black with orange, yellow, or red markings. The forewings which are frequently opaque and coriaceous have, in the more typical members of the division, two large irregular white or coloured areas, and vary from a blackish-purple to black or bronze, while the abdomens are black, yellow, green or red.

The less conspicuous species are pale-brown, chocolate, or blackish, with indistinct patterns on the wings, while the wedge-shaped insects belonging to the genus *Ipo* have transparent forewings. There is a fairly considerable range in size, the biggest species being about fifteen millimetres long, and the smallest five millimetres. The pigment causing the bright coloration of the abdomen in such species as *E. distincta* and *E. pulchra*, is carried in the hypoderm, the cuticle itself being colourless. Many species show a considerable variation in the relative size of the markings on the thorax and tegmina, and graded series can be arranged, the insects at each end being very dissimilar in detailed colour pattern.

Morphological studies have been made chiefly with *E. distincta*, so that, unless otherwise mentioned, the following notes refer to this species.

E. distincta is one of the largest insects of the group, the females being fifteen millimetres long from the apex of the head to the tip of the folded forewings. In order to give those readers of this paper who are not familiar with the group, some idea of the appearance of this species, a short description of it is given below.

Head: Black, excepting for the maxillary plates, and the outer halves of the lorae, which are white, the eyes, which are black, with a variable number of longitudinal white bands; and the labium, which is brown with a white tip.

Thorax: Pronotum and scutellum, black, the rest scarlet.

Forewings: With the exception of two irregular white spots, black with a purplish sheen.

Hindwings: Smoky grey, with an even more pronounced purplish sheen than the forewings.

Legs: Coxae, and the proximal halves of the femora, scarlet; the distal halves of the femora, the tibiae and tarsi, black, but for the first tarsal segments of the hind legs, which are white. Hind tibiae quadrilateral, two edges bearing rows of weak spines, one edge spineless, and the fourth bearing a spur, or occasionally two spurs, with mobile spines at their apices.

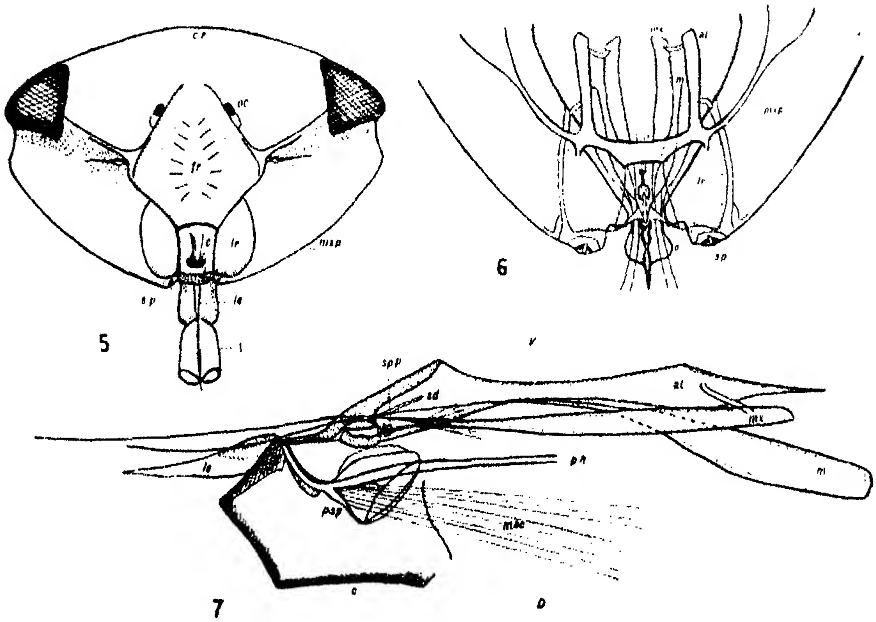
Abdomen: Scarlet.

Myers (1928) states that some of the most controverted questions in external insect anatomy have concerned the interpretation of Hemipterous head structure. The present writer is therefore content to leave the controversy to those more qualified to take part in it, and so only a brief description of the head, illustrated by text-figures, is given here, the nomenclature employed being taken from the paper on Cicadan morphology referred to above, which has been found invaluable for comparative purposes.

Head.—Viewed from in front, the head (Text-fig. 5) has a flattened appearance, and is considerably broader than long. The white genae (maxillary plates) which bear sensory pits on their anterior inturned margin, similar to those found in some Cercopids (*Philagra* sp.), occupy fully half the total area of the head. Overlapping these sclerites, and lying along the margin of the clypeus and frons, are the small lorae. The frons which is not appreciably swollen in this species, is diamond-shaped. The anterior edges of the genae, lorae and clypeus are bent at an obtuse angle to the rest of the sclerites, and lie parallel to the long axis of the body. The labium is three-segmented, the tip reaching the coxae of the middle pair of legs.

The sclerite lying above the frons is the crown or vertex. In the adult and last instar nymph of this species, there is no recognizable suture between these two sclerites, although one is present in the other nymphal instars. The crown

bears the ocelli, which lie along the edge of the frons. In the adult this sclerite lies entirely in a ventral position, but for a narrow dorsal border on a plane with the pronotum. As may be seen in Text-figures 2 and 3, the crown extends further dorsally in the nymphs. Although the epicranial suture is not visible



Text-fig. 5.—Head of *E. distincta*. *l.*, labium; *lc.*, labium-epipharynx; *sp.*, sensory pore; *c.*, clypeus; *lr.*, lorum; *mxp.*, maxillary plate; *fr.*, frons; *oc.*, ocellus; *cr.*, crown.

Text-fig. 6.—Anterior part of the head of *E. distincta*, viewed from behind. The two maxillary plates have been separated at their junction; the lorae are from this view-point beneath the maxillary plates. *mx.*, maxilla; *at.*, maxillary apodeme; *m.*, mandible; other lettering as in Text-fig. 5.

Text-fig. 7.—Median section through the part of the head shown in Text-fig. 6. *psp.*, pharyngeal sucking-pump; *msc.*, dilator muscles of pharynx; *ph.*, pharynx; *spp.*, salivary pump; *sd.*, salivary duct; other lettering as in previous figures.

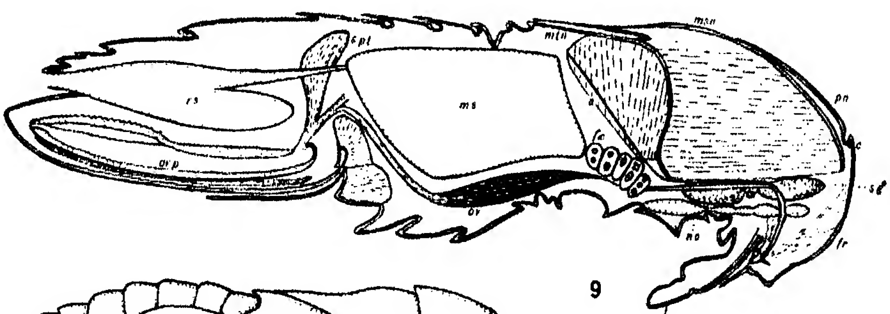
in adult insects, yet it is present in the nymphs, excepting for those in the fifth instar, and it is along this suture that the skin of the head splits at each ecdysis. The lateral arms of the suture lie along the margin of the frons, and the stem of the Y runs posteriorly to the hind margin of the head. Before casting its skin, a nymph will firmly insert its stylets into the tissue of the leaf or twig on which it is resting. The old skin is thus anchored down, and remains attached to the plant after the insect has left it.

Text-figure 6 is a semi-diagrammatic representation of the lower (anterior) part of the head capsule, viewed from behind. The maxillary plates, which have been separated and pulled apart, in order to show the hypopharynx and salivary pump, lie on top (from this viewpoint) of the lorae. The body of the tentorium,

which for the sake of clarity is not shown, joins the apices of the maxillary apodemes. Each mandible is attached to the wall of the head capsule at the junction of a lora, maxillary plate and the frons. As will be seen from the diagram, their point of attachment does not lie so far back in the head as that of the maxillae.

Text-figure 7, also semi-diagrammatic, is a median section through the part of the head represented in the previous figure. The stylets are shown displaced, the mandible being freed from its connection with the head capsule. Actually the two stylets join the opposite pair at the meeting place of the pharyngeal opening and the efferent duct of the salivary pump, and then lie in a groove between the hypopharynx and epipharynx, and thence along the trough of the labium. The apposed stylets form a closed tube, the barbed mandibles enclosing the finer maxillae.

The pharynx consists at first of a highly chitinized tube, which leads into the sucking-pump. The pharyngeal muscles are inserted into the dorsal wall of the invaginated portion of the sucking-pump, the other ends being attached to the inner surface of the frons. The rest of the digestive system is described later, in the section dealing with the internal anatomy. Below the sucking-pump (above in the diagram) is the salivary pump. The following description of this organ given by Myers, though referring to the Cicadidae, is equally applicable here. "The salivary pump is a tiny but tough chitinous cylinder, or elongate bell of transparent material, lying beneath the trough-like frontal plate. The piston or plunger . . . . is darker in colour. The pump anteriorly continues into a narrow heavily chitinised tube opening near the mouth pore. Posteriorly the



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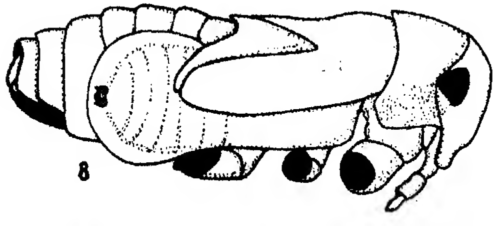

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Text-fig. 8.—*E. distincta*, last instar nymph, with attached parasitic lepidopterous larva.

Text-fig. 9.—*E. distincta*, vertical longitudinal section through a female, diagrammatically represented. The section was cut when the mesenteric sac was fully distended with air. *l.*, labium; *fr.*, frons; *c.*, crown; *pn.*, pronotum; *msn.*, mesonotum; *mtn.*, metanotum; *sg.*, salivary gland; *nc.*, nerve cord; *fc.*, filter-chamber; *a.*, aorta; *ov.*, ovary; *ms.*, mesenteric sac; *spt.*, spermatheca; *rs.*, rectal sac; *ovp.*, ovipositor.

shaft of the plunger expands into two branches, each serving for the insertion of a wide but powerful protractor muscle."

Thorax.—The detailed morphology of the thorax has not been investigated. Viewed dorsally, the large pronotum and scutellum are the only visible sclerites. The prescutum of the mesothorax is entirely covered by the pronotum, and the prescutum of the metathorax, which is a bilobed plate, is bent at right angles to the scutum, the latter being overlapped by the scutellum of the mesonotum (Text-fig. 9).

Legs.—The legs are of interest, since it is owing to the fact that the hind tibiae of the majority of the species bear a few prominent spurs, and do not have rows of long spines, that they are so often mistaken for Cercopidae. The legs of the nymphs are long and spider-like, and since they do not jump there is no great development of the hind tibiae; these are relatively longer in the adults, which also have three instead of two tarsal joints on each leg, the extra segment being formed by the division of the ultimate nymphal ones.

Front Legs.—The interior sides of the front femora and tibiae each bear a row of spines with broad bases, no doubt of service to the insect in enabling it to retain a good grip of its food-plant. The second, third and fourth instar nymphs each have two rows of spines on the femora and one row on the tibiae; the fifth instar nymphs have two rows on both segments, as does also the adult, though those borne by the latter on the tibiae are greatly reduced.

Hind Legs.—The tibiae of the nymphs in the first three instars are rounded, and have many rows of small spines. Those of the fourth instar nymphs are quadrilateral in section, though the edges are not well defined. Each edge bears a row of spines, the outside ones possessing many more than the inside ones. The tibiae of the fifth instar nymphs are similar to those described for the fourth instar, but the spines are relatively shorter and their bases more protuberant, and the ridges of the segment better defined.

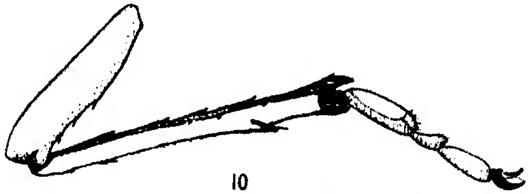
The number and arrangement of spines on the adult tibiae (Text-fig. 10) is somewhat variable. However, the ventral outside ridge invariably carries one or two large spurs with apical spines, and the dorsal ridge, though sometimes spineless, usually bears from six to eight small spines on its proximal half. The interior ridges each bear from three to six small spines.

Venation.—Although the fore wings are thick and opaque, the veins are clearly visible. The venation is basically similar throughout the tribe, though there are two distinct types, one such as that of *E. distincta* (Text-fig. 11) and the other in which the apex of the wing, instead of being reticulate, has four or five large apical cells. *E. bicincta* is an example of the latter and more primitive type (Text-fig. 12). It is impossible to say definitely whether the subcosta actually occupies the position shown in the text-figures, or whether it is fused with the radius. It is even possible that it may be absent.

Wing Coupling.—The wing coupling apparatus is very simple. There is a small hook-like flap on the costal margin of the hind wing, just above the fork of the radius. This catches on to the thickened anal margin of the tegmen, the thickening extending nearly as far as the distal end of the claval suture.

Male Genitalia.—The male genitalia of this species (Text-fig. 13) have previously been figured by Singh-Pruthi (1925), who gives the following description of them: "Basal plates small, fused with each other, forming a transverse plate connecting the two parameres. Segmental membrane round the base of the aedeagus very stout, fairly wide, especially in the proximal region, with a stout

dorsal outgrowth from the base; the latter free of the segmental membrane, and therefore not corresponding to the basal strut in the above forms. Parameres long and stout. Subgenital plates very large, leaf-like, bearing each a style-like process in the distal region."



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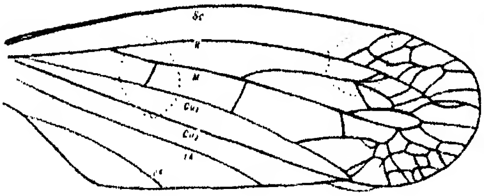

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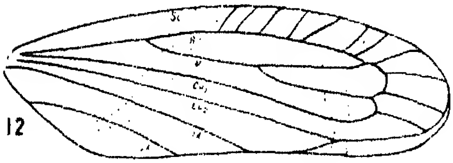

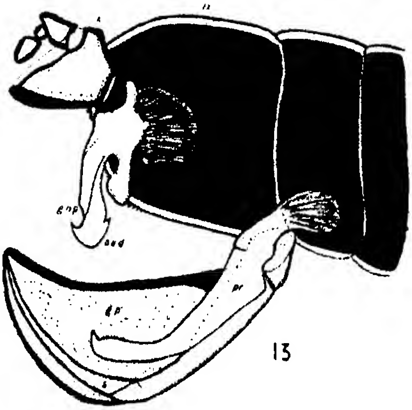

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Text-fig. 10.—Hind leg of *E. distincta*.
Text-fig. 11.—Forewing of *E. distincta*.
Text-fig. 12.—Forewing of *Eurymeloides bicincta* Erichs.
Text-fig. 13.—Vertical section through the male genitalia of *E. distincta*. *aed.*, aedeagus; *gnp.*, gonopore; *gp.*, sub-genital plate; *pr.*, paramere; *s.*, style.

Remarks.—"The reduction of the basal plates, thickening of the body wall round the aedeagus base, the fairly wide aedeagus, flap-like sub-genital plates, etc., remind us of the genitalia in the Cercopidae. However, the presence of the basal plates, though in a rudimentary condition, and the absence of a distinct periandrum, decide its relationship with the Jassidae."

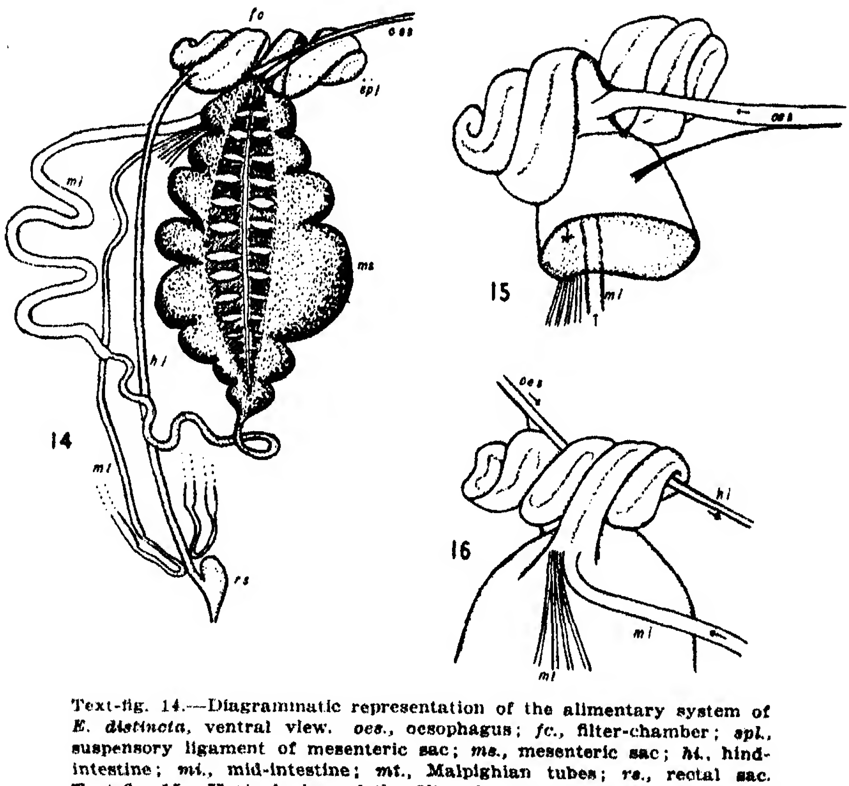
Female Genitalia.—The female genitalia (Text-fig. 9) conform to the normal type found in this family. They consist of three pairs of valves, the inner pair being fused along the greater part of their length, and forming the saw with which the slits cut in bark for the reception of the eggs are made. The one marked development in this species is that the seventh sternite is produced posteriorly into two large flaps, which reach from a point anterior to the base of the ovipositor to fully a third of its total length.

Internal Anatomy.

Digestive System.—The pharynx and sucking-pump have already been described. Posterior to the latter, the gut is a narrow chitinous tube, which

dilates just below the brain. To this swollen portion are attached numerous dilator muscles, and the anterior extremity of the aorta is intimately connected, apparently with the wall of this sac. At this point the oesophagus is bent, so that it runs at right angles to the fore part of the alimentary canal (Text-fig. 14). Posteriorly it enters the anterior lobe of the stomach. This lobe, the filter-chamber, is generally opaque, except in early summer, after the insects have emerged from hibernation, when it is more or less transparent. It is apparently coiled, this appearance being due to the fact that the stomach enwraps very closely the coiled and twisted hind part of the mid-intestine.

Licent (1912) has investigated this structure in a number of Homoptera, and remarks in connection with the family to which this insect belongs: "Chez les autres Jassidae [other than the Typhlocybinii], et chez les Membracidae, . . . la partie postérieure du médiintestin pénètre et serpente plus ou moins longuement dans la paroi d'un diverticule dorsal bien constitué, dépendant de la région antérieure; les régions proximals des tubes de Malpighi se comportent comme la partie postérieure du médiintestin, l'ensemble constitue un filtre qui évacue



Text-fig. 14.—Diagrammatic representation of the alimentary system of *E. distincta*, ventral view. *oes.*, oesophagus; *fc.*, filter-chamber; *spl.*, suspensory ligament of mesenteric sac; *ms.*, mesenteric sac; *hi.*, hind-intestine; *mi.*, mid-intestine; *mt.*, Malpighian tubes; *rs.*, rectal sac.

Text-fig. 15.—Ventral view of the filter-chamber of *E. distincta*. The coils on the right have been folded back to show the point of entrance of the oesophagus. Lettering as in Text-fig. 14.

Text-fig. 16.—Dorsal view of the filter-chamber. Lettering as in Text-fig. 14.

directement dans l'intestin postérieur la grande masse d'eau de sève". Figures 6 and 7, Plate xi, are microphotographs of longitudinal sections through the filter-chamber and mesenteric sac. The manner in which the stomach is folded round the mid-intestine is clearly shown in both photos, while in Figure 6 may be seen two Malpighian tubes cut through obliquely, and the narrow duct joining the filter-chamber to the mesenteric sac.

The posterior lobe of the stomach, here called, after Myers, the "mesenteric sac", is a large thin-walled sac, usually brown in colour, due to its contents. When at its normal size in the summer, its sides are folded, and the dorsal and ventral surfaces puckered into a series of small invaginations lying on either side of the median line. In the late summer and autumn, prior to hibernation, when the reproductive organs and accessory glands are small, the sac is so distended with air as to fill the entire abdominal cavity, so that the other organs are squeezed against the body-wall.

From the base of the sac the mid-intestine ascends, the proximal third being narrow and colourless. The distal two-thirds are wider, and finally, together with the four Malpighian tubes, enters the filter-chamber (Text-fig. 16). The point of attachment of the Malpighian tubes to the gut is hidden. For the greater part of their length they are white in colour, though the two extremities are transparent. The hind-intestine emerges laterally from between the coils of the filter-chamber, and runs straight to the rectum, the rectal sac being large and pear-shaped. The distal extremities of the Malpighian tubes are joined in pairs. The loop formed by the junction of each pair lies against, and is superficially attached to, a side of the hind-intestine anterior to the rectum. Licent (1911) has shown that the Malpighian tubes among the Homoptera terminate in a number of different ways, the type here described being of the same nature as that shown by this author to be present in *Macropsis lanio*.

Salivary Glands.—The salivary glands (Text-fig. 17) are paired organs, lying on each side of the head, and extending well into the prothorax. They have three component parts; a large semi-opaque bilobed gland, at the junction of the lobes of which lies a more transparent gland, consisting of a number of lobules, and a filamentous gland joined to the bilobed one close to the point of attachment of the salivary duct. The salivary ducts from each side of the head meet just behind the salivary pump. The two ducts join to form a single short canal which enters the pump on its ventral side.

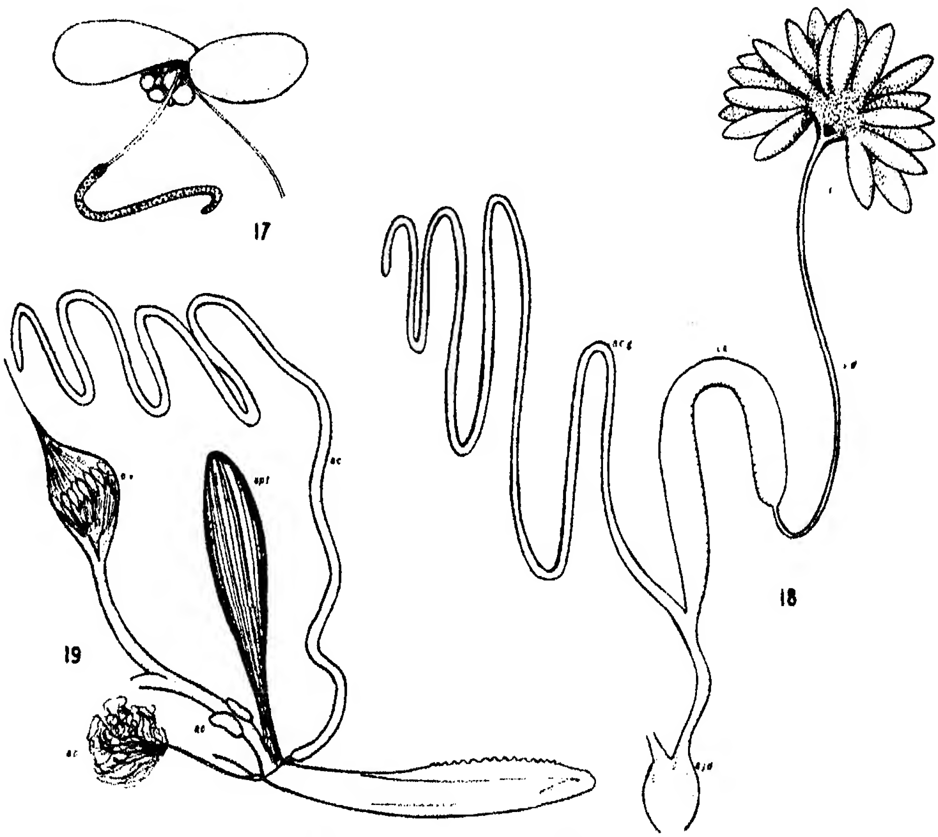
Pseudovitellus.—Lying along each side of the abdomen is a long flattened gland with three constrictions, which divide it up into four connected parts. This gland, which is surrounded by fat-body though quite distinct from the latter, is pale-pink in colour and apparently ductless. The colour, and that of the testis, in this species is probably derived from the same substance as that which colours the abdomen scarlet. The gland, presumably the pseudovitellus, is regarded by some authors as being nutritive, and by others as having an excretory function.

Physiology.—A clear account of the mechanism of feeding and physiology of the Cicadidae, which applies equally well to these Homoptera, is given in the paper by Myers already referred to (pp. 450-453).

Saliva is forced down the smaller of the two channels formed by the apposition of the maxillary stylets. If an insect is held for a moment between finger and thumb, it will exude a drop of saliva. The plant-sap is drawn up the other larger maxillary channel by the action of the pharyngeal sucking-pump. From the oesophagus it enters the filter-chamber through the oesophageal valve. The filter-

chamber is sometimes found lying transversely along the top of the mesenteric sac as in Text-figure 14, and sometimes projecting into the thorax, the coils then being at right angles to the other position. It has been noticed that although the filter-chamber is a dense white colour, and does not take up stain (methylene-blue) like the rest of the gut, yet in insects that have reproduced and have not much longer to live, it is transparent and flaccid.

What exactly happens to the sap in the filter-chamber is somewhat uncertain. The generally accepted hypothesis is that the food is here separated by osmosis into the more liquid portion consisting of water and excess sugars, which passes direct into the hind part of the mid-intestine, and the more solid portion which enters the posterior division of the stomach, the mesenteric sac. The mesenteric sac, which is lined with digestive epithelium, leads from its base into a narrow tube, also absorbent, and digestive. The distal, wider and longer part of this



Text-fig. 17.—Salivary gland of *E. distincta*.
Text-fig. 18.—Male reproductive organs of *E. distincta*, prior to the swelling of the vesiculae seminales. *t.*, testis; *vd.*, vas deferens; *vs.*, vesicula seminalis; *acg.*, accessory gland; *ejd.*, ejaculatory duct.
Text-fig. 19.—Female reproductive organs and ovipositor of *E. distincta*. *ov.*, ovary; *spt.*, spermatheca; *ac.*, accessory glands.

tube contains in its walls, large cells, which are filled with chalky granules. This part, which is excretory, enters the filter-chamber, and inside it joins the hind-intestine. The rectal sac is large, but the excrement is not expelled in a forcible manner, as with so many Homoptera.

Male Reproductive Organs.—The testes (Text-fig. 18) are large rosette-shaped organs, pale-pink in colour. Each testis in this species consists of a great many lobes, though those of *E. pulchra* have only eight. The vas deferens from each gonad runs into a large curved vesicula seminalis, which in the breeding season swells to such a size as to fill the greater part of the abdominal cavity. Before entering the ejaculatory duct, each vas deferens is joined at the base of the vesicula seminalis by a very long thin-walled accessory gland.

Female Reproductive Organs.—The oviducts from the two ovaries (Text-fig. 19) are short. Posteriorly they join to form a common oviduct or vagina, along each side of which lies a kidney-shaped accessory gland. Just before reaching the base of the ovipositor, the vagina is joined by the spermatheca, and immediately posterior to this is the termination of a very long unpaired accessory gland. Finally, lying anterior to the ovipositor, and attached to the base of the common vaginal and spermathecal canal, are paired, much-coiled filamentous glands. The spermatheca is a thick-walled muscular sac which, in insects that have just reached the last instar, is deflated and mushroom-shaped. Later, when it fills out, it is as shown in the figure. The unpaired accessory gland opens between the base of the inner pair of valves of the ovipositor. Possibly its function is to supply the froth with which the nests are sealed.

Nervous System.—The central nervous system consists of the brain, suboesophageal ganglion, and two other ganglia situated in the thorax, the hindmost of which passes posteriorly into a single cord, that splits into two on entering the abdomen. From the brain are given off laterally the big optic nerves, and from the anterior centre of each lobe, the ocellar nerves. The suboesophageal ganglion is longer though narrower than the brain, and is joined to the first thoracic ganglion by two stout connectives. This ganglion is separated from the last one by a narrow waist. There is no aperture between the two masses, the hindmost of which is large and pear-shaped, and consists of fused thoracic and abdominal ganglia.

Taxonomic Notes.

It has already been mentioned that the present classification of this Tribe is in a very unsatisfactory state. The late Professor C. F. Baker had prepared a tentative classification, but this was never published. Mr. W. E. China of the British Museum has lent the present author a manuscript key to the Tribe, prepared by him in 1926. With the aid of this key and the co-operation of Mr. China, it is hoped that it will shortly be possible to undertake the work of revision. This will entail the splitting up of the present genera into a number of new ones.

It is apparent that the larger forms at present grouped together in the genus *Eurymela* L. and S., are more specialized than the smaller ones now placed in the genus *Eurymeloides* auctt. Among the primitive characters of the latter genus, to which attention has already been drawn, are the simple venation, and the possession of eight lobes in each testis. It may be presumed also that the few spines and spurs borne on the hind tibiae of the larger forms, are evidence of specialization by reduction. Also the frons in the head of the smaller forms is

separated by a distinct suture from the vertex or crown, though this is not so in the adults of the larger species.

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EXPLANATION OF PLATE XI.

1.—Eucalyptus twig, showing the arrangement of the nests of an unidentified species of *Eurymeloides*.

2.—Closer view of the same twig as shown in Figure 1, to show the heads of the emerging pronymphs.

3.—Last stage in the process of hatching, showing three pronymphs, and a nymph which has just cast its pronymphal skin.

4.—Eucalyptus twig; the young nymphs feed at the base of the new growth.

5.—*Eurymela rubrovittata* A. and S.

6, 7.—Longitudinal sections through the filter-chamber and mesenteric sac of *Eurymela distincta* Sign.

TRICHOPTERYGIDAE OF AUSTRALIA AND ADJACENT ISLANDS.

DESCRIPTIONS OF FIVE NEW GENERA AND TWENTY NEW SPECIES.

By Cedric Deane, A.M.I.E.Aust.

(Twenty-three Text-figures.)

[Read 24th June, 1931.]

In this second paper on the Trichopterygidae twenty new species are described under ten genera, five of the latter being new. Of the new species twelve are island forms, not yet having been found on the mainland, although one, *Philagarica parva* from Lord Howe Island, is very closely allied to *P. agilis* Deane, from the Macleay River district of New South Wales. This is another example of the close alliance between the faunas of this island and the continent of Australia.

In the majority of the genera from the Australasian Region the metasternum attains the sides of the body, just as in the forms from the European Region those possessing this character are in the majority. Blind beetles are better represented in Australia than in other parts, there being one in America, none in Europe, Asia and Africa, whilst there are eight recorded up to date in Australia.

Since the publication of the first paper I have acquired a knowledge of the methods of mounting insects on glass slides for the microscope, and the advantages of this method of examination. In this I have been greatly helped by Mr. E. B. Blackbourne, who made the first slides for me.

The author hopes in a subsequent paper to draw up a table of classification for the Trichopterygidae. The diversity of forms occurring suggests a complex classification, as in the large family Carabidae, rather than a simple one such as in, say, the Anthicidae. This seems to indicate great probable developments for the Trichopterygidae in the future. In the Carabidae there is great structural difference between the genera *Mormolyce* and *Catascopus*, and between *Silphamorpha* and *Notonomus*; and in the Trichopterygidae the separation is equally pronounced between *Trichopteryx* and *Nanosella* or between *Ptilium* and *Rodwayia*. Contrast this situation with that in the family Anthicidae, where all the present genera are fairly closely allied. The localities, from which the species described in these pages have been collected, are comparatively few, and although some are widely separated geographically, yet others are neighbouring. In spite of this, widely different forms appear in the one locality or in adjacent ones. The large amount of material forwarded from the South Australian Museum contains none of the species appearing amongst the contributions forwarded by C. Oke; also the specimens from Canberra, per Miss Winifred Kent Hughes, contain two of *Ptenidium*, which genus has not appeared in either of the other two collections.

The true *Trichopteryx* occurs in Australia and adjacent islands. These forms conform closely to the set of characters laid down by authors in their descriptions

for the genus. There are, however, superficial distinctions between the Trichopteryx fauna of this region and that of the European; the majority of the English species are more nitid, blacker, less pubescent, and the pubescence is shorter than in the Australasian forms. They are also less sharply quadrate. But the main generic features are somewhat constant around the Globe. Now in *Ptilium* this is not so; this is a genus whose species appear to range widely with certain characters showing much variation; these characters are the posterior angles of the prothorax, the terminal segments of the antennae, and the degree of separation of the hind coxae, characters which are usually looked upon as of generic rank, and yet since no line can be drawn we must merge them all into one genus.

Matthews found certain species to be so widely distributed as to occur in most parts of the world. Contrasted against this may be set the fact that I have not found any two widely separated localities yield the same species, although a comparatively large amount of material has been collected. Moreover, the differences between certain species of *Trichopteryx* from neighbouring localities in Australasia, though not always great, are nevertheless as great or greater than between some of the English species, e.g., *T. bovina* Mots., *T. atomaria* De Geer, and *T. serricans* Heer.

EPIBAPTUS, n. gen. (Text-fig. 1.)

Somewhat elongate, lightly convex, margin much interrupted, widest across elytra. Head subspathulate, narrow, rather convex, front gently rounded, sides sinuous, genae full. Eyes large, prominent, set somewhat obliquely forward. Antennae long, eleven-segmented; scape rather large, barrel-shaped, pedicel invert obconic; 3 to 7 slender cylindric, 8 swollen at middle, 9 and 10 large, flask-shaped, 11 acorn-shaped, 8 to 11 strongly setose, the setae being longer than the corresponding segments on which they are placed. Pronotum irregular, convex, widest at middle; anterior margin convex at centre, posterior margin triconcave; lateral margins concave on posterior half, forming posterior angles, slightly convex on anterior half, with reflex margins; bifossate near base; fossae transverse. Scutellum depressed near base, rather long in proportion to width; anterior margin convex, sides concave. Elytra sub-elliptic, convex, widest at middle, rather narrow at base, ample, completely concealing abdomen. Legs slender. Tibiae long, anterior straight, posterior slightly curved. Tarsi rather robust, tapering to apex.

Apparently nearest to *Dimorphella* Matth., of Brazil, South America, from which it differs notably in having eyes much larger, head narrower in front, pronotum transverse and elytra widest at or near middle, these also covering abdomen. The general shape of the pronotum is only faintly suggestive of the American genus.

Genotype, the following species.

EPIBAPTUS SCUTELLARIS, n. sp. Text-fig. 1.

Scarcely nitid, sparsely pubescent, punctate, cinnamomeous. Head nitid, dark-brown, finely punctate. Antennae, scape and pedicel light-brown; 3 and 4 stramineous, 5 to 8 lurid, 9 to 11 dark-brown; segments 1 to 7 sparsely and irregularly, 8 to 11 strongly, setose; setae on 8 and 9 cream on apical, brown on basal half; setae on 10 and 11 almost black. Eyes silvery; facets coarse. Legs light-brown. Pronotum nitid, smooth, glabrous. Scutellum nitid, glabrous, lurid.

Elytra somewhat nitid, sparsely pilose, coarsely and irregularly punctate, walnut-brown, punctures shallow, hairs golden-brown; apices dehiscent. Legs light-brown. Length, 0·86 mm.; width, 0·38 mm.

Habitat.—Emerald, Victoria (C. Oke). Fern Tree Gully (C. Deane).

Type in Coll. Deane.

The metasternum reaches the sides of the body, the episterna not being visible. The coxae are small, the posterior pair being widely separated. The wings are narrow and the stalk long and slender, thickening a little gradually towards the base and apex.

PARATUPOSA, n. gen. (Text-fig. 2.)

Elongate, cylindro-elliptic, somewhat subereous, widest across elytra. Head subtrapeziform, prominent, largely visible from above, widest across eyes. Eyes visible from above, of medium size. Antennae having the club equal in length to the remainder of the flagellum; scape moderate, pedicel rather large, of peculiar form, its apex suddenly reduced a little in diameter giving the appearance of an extra short broad segment; segment 3 cylindric, 4 subcylindric, 5 barrel-shaped, 6 nearly spherical, 3 to 6 of approximately equal thickness; 7, 8 and 9 transverse, increasing in width; 10 and 11 very large; apical segment wide over basal half, suddenly reduced in diameter just beyond middle; sub-apical segment bi-truncate-conic, somewhat transverse, the sides of basal half only slightly tapering; length of antenna 0·22 of length of insect. Pronotum convex, widest before base, basal margin straight, anterior and lateral convex; posterior angles very obtuse, anterior obsolete. Scutellum medium, lateral margins convex. Elytra widest at or just before middle, lightly convex or somewhat depressed; rounded and dehiscent at apex, not reaching to apex of abdomen. Abdomen elongate, four apical tergites exposed. Coxae: anterior moderate, elliptic, contiguous; intermediate small, globular, contiguous; posterior large, flat, subdeltoid, almost contiguous. Femora: anterior narrow, of medium length; intermediate broad, rather short; posterior small. Tibiae and tarsi subequal.

This genus differs from the only closely allied genus, *Nanosella*, from Central America in having the pedicel of antenna as long as the scape and segments 7, 8 and 9 transverse ovate-elliptic instead of scutellate, pronotum widest at one-third from base to apex instead of at base, elytra dehiscent at apex and exposing much more of the abdomen.

Genotype, the following species.

PARATUPOSA PLACENTIS, n. sp. (Text-fig. 2.)

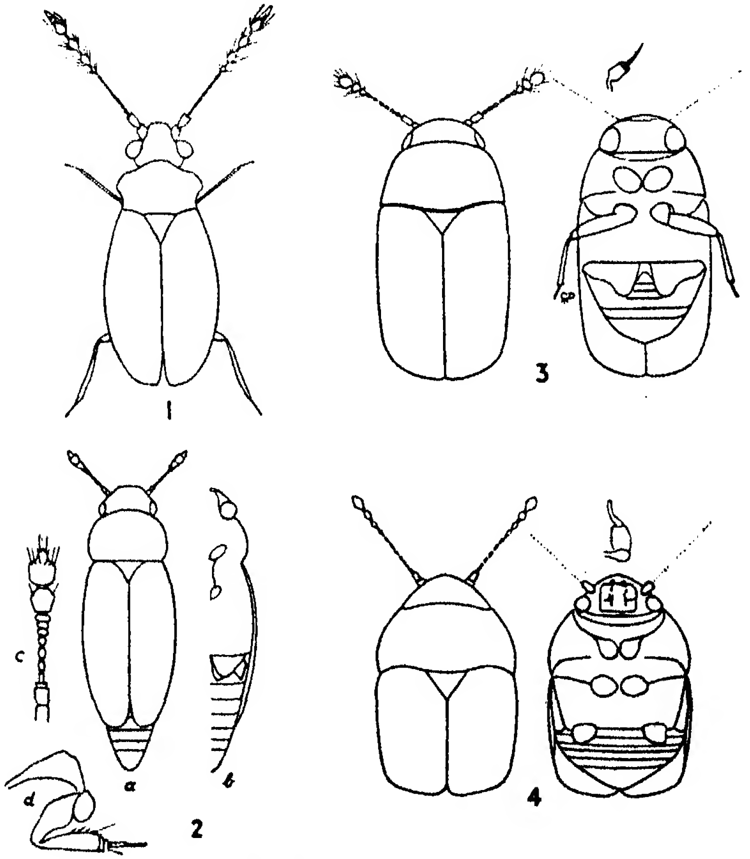
Light walnut-brown, pubescent. Head more or less narrowly rounded in front, convexity feeble above, sides oblique; sparsely and irregularly pubescent; dark-brown especially near eyes. Eyes black, rather conspicuous. Antennae pale-yellow, vitreous, almost glabrous. Palpi stramineous. Pronotum convex, paler on centre of disc, darker at all margins. Scutellum of equal shade to elytra. Elytra strongly pubescent, slightly darker at lateral margins, yellow at apices. Abdomen yellow, margins of ventral segments lightly setose, setae yellow. Pygidium fringed with more numerous hairs; these short. Length, 0·39 mm.; width, 0·13 mm.

Habitat.—Mt. Lamington, N.E. Papua, 1,300 to 1,500 ft. (C. T. McNamara).

Type in South Australian Museum, cotypes in Coll. A. M. Lea and Coll. Deane.

ISOLUMPIA, n. gen. (Text-fig. 3.)

Obovate-quadrate, widest across elytra, somewhat depressed or very slightly convex, margin almost entire. Head medium, produced downwards at mouth, widely rounded in front, rather broad, convex. Eyes visible from above. Antennae of moderate length, 0·32 of the length of body, rather robust, strongly clavate; scape medium, pedicel rather large, cylindric; 3 to 6 globular, 7 to 9 conic, 10 and 11 nearly spherical; 10 broader than long, 11 longer than broad; 9, 10 and 11 setose, forming the club. Palpi with terminal segment long, the broadest segment sub-



1.—*Epibaptus scutellaris*, n.g. et sp. 2.—*Paratuposa placentis*, n.g. et sp.
3.—*Isolumpia divina*, n.g. et sp. 4.—*Etronia convexa*, n.g. et sp.

cylindric. Pronotum widest at base, base as wide as base of elytra; lateral and anterior margins convex; posterior angles well formed, anterior obsolete. Scutellum deltoid, not large. Elytra subquadrate, sides parallel, apices not dehiscent, concealing abdomen. Coxae: anterior rather large, oval, oblique, contiguous; intermediate rather small, separated; posterior large, deep, attaining sides of body, not contiguous.

Does not appear to be closely allied to any other genus; its nearest ally is probably *Philagarica*, with which it has in common the broad posterior coxae; it differs conspicuously in the shorter and differently constructed antennae, the parallel form of the body and the head and eyes being largely visible from above.

Genotype, the following species.

ISOLUMPIA DIVINA, n. sp. (Text-fig. 3.)

Pubescent, light-brown. Head sparsely pubescent. Eyes black. Palpi cream-coloured. Antennae and underside of head and mouth parts flavous to cream. Upper surface of head, pronotum, scutellum and elytra uniformly brown. Metasternum brown shading to light-brown near posterior margin. Prosternum and mesosternum yellow. Abdomen with basal ventral segments dark-brown, apical segments brown. Apical angle obtuse but sharply defined. Legs flavous. Posterior coxae brown at centre, yellow at edges. Tarsi stramineous, slender, rather long; claws small. Length, 0·4 mm.; width, 0·2 mm.

Habitat.—N.E. Papua; Mt. Lamington, 1,300–1,500 ft. (C. T. McNamara).

Type in South Australian Museum, cotypes in Coll. Deane.

ETRONIA, n. gen. (Text-fig. 4.)

Oval, convex, margin entire, widely rounded in front, truncate behind. Head rounded in front, broad, convex, easily visible from above, widest at base, deeply inserted in prothorax. Eyes little visible from above, small. Antennae 11-segmented, rather long, of normal thickness; scape large, barrel-shaped; pedicel medium, cylindric; 3 and 4 cylindric, 5 and 6 subcylindric, 7 and 8 slightly swollen at middle, 9 to 11 forming the club, 9 globular, much smaller than 10, 10 smaller than 11. Setae sparse, not longer than the segments on which they are set. Palpi: terminal segment thickened at base, filling apex of subterminal; subterminal segment barrel-shaped; next swollen at apex, forming seat for the one above. Pronotum very convex, widest just before base; marginal curvature uniform; posterior angles well defined, hardly acute. Scutellum rather large, lightly convex; sides a little convex. Elytra quadrate, almost rectangular, lightly convex; sides subparallel, apices broad, not dehiscent at apex, covering abdomen. Abdomen short, not spinose, strongly setose. Metasternum not reaching sides of body; episterna widening posteriorly. Coxae: anterior subglobular, medium, contiguous; intermediate subtriangular, rather small, almost contiguous; posterior subtriangular, rather small, remote. Legs robust. Wings: breadth of membrane normal.

Allied to *Trichopteryx*, which it resembles in general form, structure of antennae, underside of head and mouth parts, the disposition of prosternum and the shape of the anterior and intermediate legs. It is clearly separated from this genus, however, by the metasternal episterna, which are more suggestive of *Actinopteryx* and *Neotrichopteryx*, and also by the posterior coxae and the apex of abdomen.

Genotype, the following species.

ETRONIA CONVEXA, n. sp. (Text-fig. 4.)

Nitid, setose, dark-brown and yellow. Head black, hairs or setae abundant, standing upright. Eyes black. Antennae: scape and pedicel yellow; extreme edge of apex of pedicel reddish-brown; flagellum cream-coloured. Pronotum very dark-brown, pale at posterior angles; lightly, irregularly and sparsely setose; smooth,

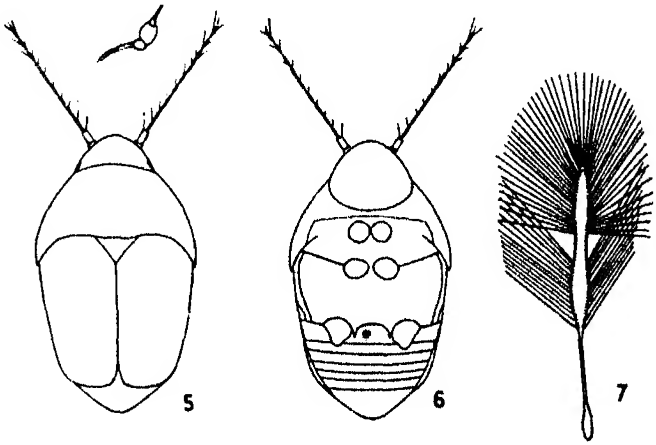
nitid. Scutellum brown, highly nitid, glabrous. Elytra yellow, transparent; the setae white. Legs yellow, setose, rather robust. Abdomen short, dark-brown. Length, 0·67 mm.; width, 0·43 mm.

Habitat.—Stewart River, Queensland (Hale and Tindale).

Type in South Australian Museum.

ACTINOPTERYX COLOSSUS, n. sp. (Text-figs. 5, 6, 7.)

Obovate, widest across pronotum, convex, dark-brown, pubescent. Head rather narrow, convex, black, pilose; somewhat nitid; clypeus slightly marginate. Eyes visible from above, rather small, silvery. Antennae long, 0·55 of length of body, slender, not clavate, setose; scape somewhat short, pedicel rather large, sub-



5-7.—*Actinopteryx colossus*, n. sp.

cylindric, yellow, darker near apex, apex rounded; segment 3 pale-yellow, 4 to 8 lurid, 3 to 6 long, cylindric, slender; 7 to 8 barrel-shaped; 9 to 11 grey, rather swollen in middle. Palpi with the globular segment ovoid, terminal normal. Pronotum widest just before base, rather narrow in front, convex, pilose, dark-brown, coarsely rugose, light-brown on posterior angles, anterior angles almost obsolete, posterior acute. Scutellum normal, sides concave, hardly depressed, not easily visible, rather concealed by pilosity. Elytra widest at base, broad at apices, somewhat depressed, dehiscent at apex, dark-brown, paler at apices, pubescent, finely rugose, hairs white, yellowish-brown at apices. Legs deep-yellow. Abdomen dark-brown. Wings: stalk long, narrow, swollen at base. Length, 0·9 mm.; width, 0·52 mm.

Habitat.—Noumea, New Caledonia (A. M. Lea).

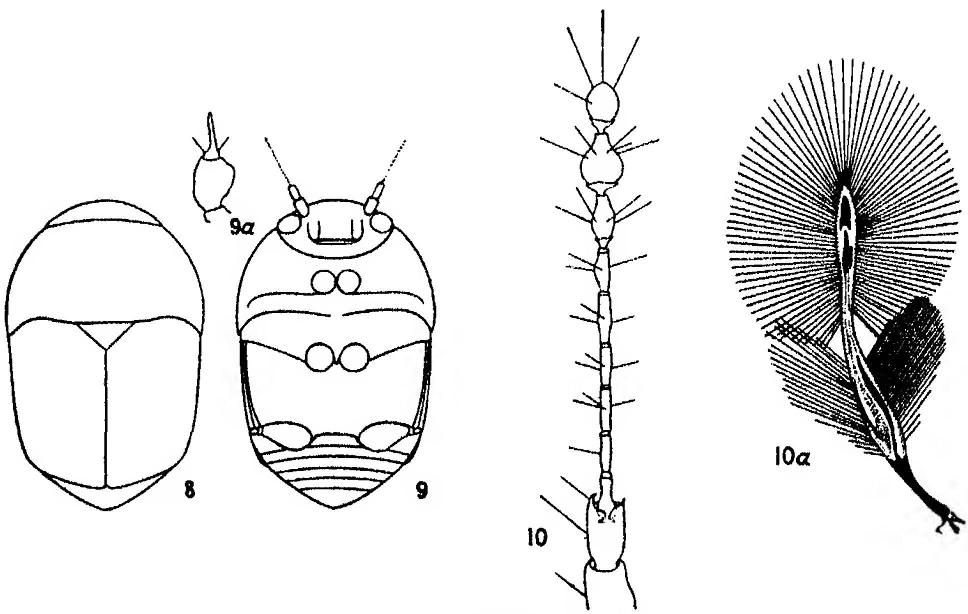
The mesosternal carina is straight and narrow and elevated, the posterior margin of metasternal episternum not reaching side. Metasternum reaching nearly to sides of body, posterior margin deeply excavated for insertion of coxae; intercoxal portion also deeply excavated. The coxae are moderately distant, deep in proportion to width, subtriangular, and not nearly reaching to sides.

The description has been rather full, including details which might be looked upon as of generic importance only, because it is realized that there may ultimately arise a difference of opinion regarding the proper genus in which to

place this species. It differs from *Trichopteryx* in form, wings, antennae, coxae, metasternum, etc., and from the true *Actinopteryx* in the metasternal episterna being visible and even conspicuous.

ACTINOPTERYX HERCULES, n. sp. (Text-figs. 8, 9, 10.)

Oval, highly convex, blotchy-brown, pubescent, widest across pronotum. Head nearly black, somewhat nitid, broad. Eyes black, a little prominent. Antennae rather small; scape and pedicel a little flattened, reddish-brown; flagellum lurid; segments 9, 10 and 11 forming the club; 8 not swollen. Pronotum scarcely nitid, pubescence very irregular, hairs golden; widest a little before base; posterior angles normal; rectilinear portion of posterior margin extending beyond basal angles of scutellum; very dark on centre of disc. Scutellum rather short, well defined. Elytra quadrate, narrowing slightly towards apices; apices not dehiscent. Abdomen with pygidium rather broad, exposed, not spinose. Prosternum and mesosternum orange-brown, glabrous; metasternum reddish-brown, pilose; ventral plates of abdomen yellowish-brown, pilose. Metasternal episterna visible, parallel; mesosternal intercoxal process and post coxae trichopterygiform. Legs yellowish-brown, posterior rather small. Wing-stalk short, thick, slightly curved. Length, 1·12 mm.; width, 0·66 mm.



8-10.—*Actinopteryx hercules*, n. sp.

Habitat.—Ourimbah, N.S.W. (A. M. Lea).

Type in Coll. Lea, cotypes in Coll. Deane and South Australian Museum.

Owing to the general form of the insect, together with the absence of tridentate pygidium, and to the inter-post-coxal margin of metasternum, this species has been included with *Actinopteryx* in preference to adding to the number of genera carrying only one species. The chief points of difference from the typical form of *Actinopteryx* are (1) metasternum not reaching sides of body but being

separated by the episterna, which are conspicuous though rather narrow, and (2) posterior coxae broad, reaching nearly to sides.

TRICHOPTERYX FLAVIPENNIS, n. sp. (Text-fig. 11.)

Oval-quadrate, widest across prothorax, lightly convex, pilose, hardly nitid. Head somewhat narrowly rounded in front, convex, black, the hairs brown at centre, black at sides. Eyes scarcely visible from above, black. Antennae hairy; scape and pedicel large, yellow; scape barrel-shaped, pedicel cylindric; segments 3 to 11 dark-brown; 3 to 8 slender, subcylindric; 9 and 10 rather large, ovoid; 10 much larger than 9; 11 elliptic. Pronotum sparsely pilose, black, rather nitid; posterior angles dark-brown. Scutellum glabrous, rugose, black. Elytra strongly pilose, somewhat depressed, flavous, opaque; apices transverse. Wings robust, membrane cream-coloured, strongly marked, veins brown, marginal ciliae dark-brown. Pygidium exposed, faintly trispinose, hairy. Legs yellow. Length, 0·92 mm.; width, 0·56 mm.

Habitat.—Ovalau, Fiji Islands (A. M. Lea).

Type in South Australian Museum, cotype in Coll. Deane.

Does not appear to be closely allied to any other described species.

TRICHOPTERYX SYDNEYENSIS, n. sp. (Text-fig. 12.)

Widely obovate to subquadrate, widest equally across prothorax and elytra, somewhat depressed, strongly pilose, ferrugineous. Head broad, widely rounded in front, rather deeply set in prothorax, largely visible from above. Eyes cream-coloured, scarcely visible from above, rather small. Antennae: scape and pedicel large, yellow; flagellum very slender, cream-coloured; apical segment stramineous to hoary. Prothorax widest just behind middle; lateral margins unusually convex near centre; anterior angles obtuse, posterior slightly acute. Scutellum normal or rather small; lateral margins straight. Elytra widest near middle, lateral margins convex; posterior lateral angles widely rounded, medial slightly rounded, somewhat dehiscent at apex; depressed, strongly pilose, ferrugineous. Abdomen faintly trispinose. Legs lurid, of medium size; intermediate and posterior tibiae spinose on interior margins. Length, 0·88 mm.; width, 0·48 mm.

Habitat.—Sydney, N.S.W. (per Miss Winifred Kent Hughes).

Type in Museum of Division of Economic Entomology, Canberra.

TRICHOPTERYX NORFOLKENSIS, n. sp. (Text-fig. 13.)

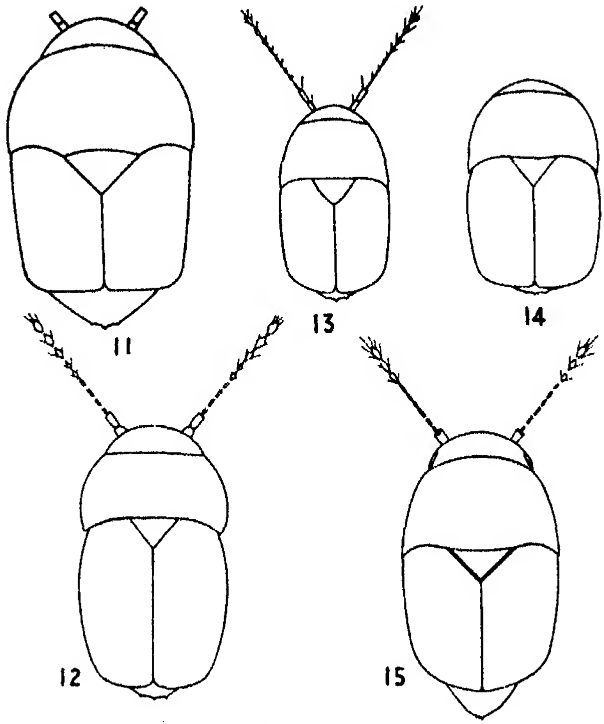
Ovate-quadrate, very lightly convex, pubescent, dark walnut-brown, finely rugose, hairs pale-brown. Head medium, evenly rounded in front, convex, sparsely pubescent; hairs very short, irregular. Eyes inconspicuous, scarcely visible from above, of moderate size. Antennae rather long; scape and pedicel yellowish-brown tipped with dark-brown; flagellum dark-brown. Pronotum widest almost at base; convex, margins lightly curved, posterior angles normal; slightly darker than elytra. Scutellum sharply defined, side margins curved; slightly darker than elytra, nearly as dark as pronotum. Elytra quadrate, lightly depressed, transparent at apical margin; pubescence very decumbent, strongly parallel. Wings dark-brown. Legs orange-yellow. Length, 0·64 to 0·74 mm.; width, 0·36 to 0·42 mm.

Habitat.—Norfolk Island (A. M. Lea).

Type in South Australian Museum, cotypes in Colls. Lea and Deane.

Compared with *T. australica* Deane, on specimens mounted in canada balsam on glass slides, the two insects respond differently when subjected to the same

treatment for clarification, removal of oils and moisture, etc. The body substance appears more robust, much less transparent, and yet the wing membranes are much clearer, being practically devoid of markings.



11.—*Trichopteryx flavipennis*, n. sp. 12.—*T. sydneyensis*, n. sp. 13.—*T. norfolkensis*, n. sp. 14.—*T. walkomi*, n. sp. 15.—*T. jocosa*, n. sp.

TRICHOPTERYX CERVINA, n. sp.

Ovate-square, convex, hardly nitid, rugose, reddish-golden-brown, scarcely and faintly pubescent in parts. Head red, almost glabrous, rather narrowly rounded in front. Eyes silvery-pink, not prominent. Antennae orange-coloured; scape short, pedicel barrel-shaped. Pronotum widest at base, darker near anterior margin, faintly rugose, thinly pubescent; hairs golden; posterior angles well formed, somewhat acute; anterior angles very obtuse. Elytra quadrate. Abdomen bright-brown, pygidium exposed, tridentate, rather sharply pointed. Metathorax and mesothorax very nitid, almost glabrous, tan-coloured. Legs robust; coxae and femora yellow; tibiae and tarsi cream-coloured. Wings very transparent; membrane almost colourless with orange-coloured markings; hairs of fringe light golden-brown. Length, 0·75 mm.; width, 0·39 mm.

Habitat.—Sydney, N.S.W. (per Miss Winifred Kent Hughes).

Type in Museum of Division of Economic Entomology, Canberra.

Differs from *T. australica* Deane, in having head shorter and more narrowly rounded in front; posterior angles of pronotum sharper but not longer; surface rugose; colour as described. The colour difference between the two species as

given in the descriptions is not due to immaturity of the specimen used for the new species. I have taken large numbers of *T. australica* Deane in all stages of maturity, and they shade from creamy-straw colour, through livid and light walnut-brown, to the standard shade, without any tint of red.

TRICHOPTERYX WALKOMI, n. sp. (Text-fig. 14.)

Oval-quadrate, lightly convex, black, somewhat nitid, sparsely pubescent, hairs hoary, finely granulate. Head broad, somewhat narrowly rounded in front, gently sloping on forward declivity, convex at sides, black, hardly nitid, scarcely pubescent. Eyes inconspicuous, but just visible from above. Pronotum subquadrate, widest at base, sides subparallel, posterior angles acute; black, nitid, sparsely pubescent, finely granulose. Scutellum rather large, clearly defined; side margins rectilinear. Elytra quadrate, parallel, scarcely dehiscent, depressed, black, pubescent. Prosternum with episterna and epimera distinct. Mesosternal intercoxal process a long narrow sharp point. Coxae: anterior large, globular, yellow, semitransparent; intermediate depressed, black; posterior very thin, broad, transparent. Femora light-brown; anterior medium, intermediate broad. Length, 0·72 mm.; width, 0·45 mm.

Habitat.—Sydney, N.S.W.

Type in Museum of Division of Economic Entomology, Canberra.

This species differs from *T. australica* Deane in having head shorter, pronotum more quadrate, posterior angles more acute and lateral margins of pronotum less convex near base; pedicel of antenna broader at apex. From *T. norfolkensis*, n. sp., it can be distinguished by form broader, pronotum more quadrate, lateral margins of scutellum rectilinear, apices of elytra less oblique.

TRICHOPTERYX JOCOSA, n. sp. (Text-fig. 15.)

Oval-rectangular, convex, black, strongly pilose, widest at the base of pronotum. Head moderately visible from above, strongly pilose, dark-brown, setae very thick, black; front moderately produced, anterior side marginal corners flattened, margins raised; mouth produced downwards, palpi globular, segment very large ovoid, stem or supporting and apical segments very slender. Eyes moderate, just visible from above. Antennae rather long to moderate; first segment concealed from above, first and second segments cylindro-conical, expanding slightly towards apex; 3, 4, 5 slender, cylindric; 6, 7, 8 somewhat barrel-shaped to sub-cylindric; 8 conic, 9, 10 oval-elongate. Scape and pedicel lurid. 3 to 8 stramineous, club grey. Pronotum widest at the base, side and front, margins convex, basal margin strongly concave at the sides, slightly concave at the middle, hind angles acute. Scutellum large, wide, triangular, yellow; anterior margin slightly concave, side margins straight. Elytra yellow near base, remainder brown; thickly pubescent, slightly tapering, widest at the base, posterior lateral angles greatly rounded, medial posterior angles not acute, not dehiscent at apex. Pygidium exposed, pointed obtusely, not tridentate. Legs light-brown. Wings: membrane narrow, marked with black; hairs of fringe black, 3·4 times as long as the width of membrane at its widest part. Length, 0·76 mm.; width, 0·42 mm.

Habitat.—Mt. Lamington, N.E. Papua (C. T. McNamara), 1,300–1,500 ft.

Type in South Australian Museum.

Differs from the typical form of *Trichopteryx* to such an extent that I was considering proposing a new genus to receive it. The notable features are head with broader front, its base unconformable with outline of prothorax, eyes more

visible from above than in the type of the genus; the pronotum also is more convex in front. The pygidium is particularly hairy, but the tridentate formation is visible with difficulty. The posterior tibiae are larger than usual.

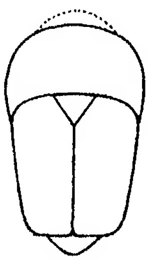
MYRMECOTRICHIS ACUTANGULA, n. sp. (Text-fig. 16.)

Ovate, somewhat depressed, walnut-brown, very pubescent. Head very dark, slightly pilose on anterior, strongly nitid on posterior, half of upper surface. Eyes rather small, black. Antennae grey, scape and pedicel lurid, the latter furnished with a large seta on anterior margin of apex. Pronotum with posterior angles lurid, strongly formed, acute; pubescence very fine and short. Scutellum of moderate size, slightly darker than elytra, distinguishable with difficulty owing to pubescence. Elytra finely granulate, quadrate, slightly tapering; apices somewhat lurid. Abdomen with pygidium exposed; dentations obsolete. Length, 0·81 mm.; width, 0·45 mm.

Habitat.—Vanua Lili, Fiji Islands (A. M. Lea).

Type in South Australian Museum.

Owing to this description having been drawn up from a single specimen, and that from a remote locality, the author has deemed it inadvisable to mutilate the insect further. The head is severed from the body and the prothorax is twisted at a considerable angle to the body. Moreover, I do not think it wise to mount a unique type specimen in balsam for a slide, as the original appearance of the creature is thereby to some extent lost. For these reasons the amount of detail given is rather meagre. The only other species of this genus is *M. aequatorialis* Motschulsky from Central America, from which the new species appears to differ in having antennae more slender, abdomen less exposed and elytra much less tapering; the upper surface is flattened instead of being strongly convex, and pubescent instead of nitid. Many other differences exist to make the new species strongly dissimilar to the old one.



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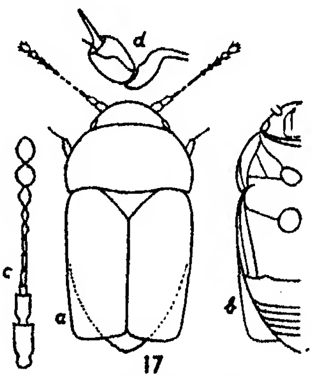

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16.—*Myrmecotrichis acutangula*, n. sp. 17.—*Neotrichopteryx grandelytra*, n.g. et sp.

NEOTRICHOPTERYX, n. gen. (Text-fig. 17.)

Subquadrate or widely obovate, somewhat depressed, very little wider across prothorax than elytra. Head largely visible from above, deeply set in prothorax, widely rounded in front, broad, convex above. Eyes rather small, easily visible from above. Antennae of medium length and form; scape large; pedicel smaller, pitcher-shaped; segments 3 to 6 slender, cylindric; 7, 8 and 9 slender, elongate-

elliptic; 10 large, nearly spherical; 11 acorn-shaped, large; clothing sparse. Palpi prominent; stem slender, curved, club large, globular; apical segment long, slender, with a stout spine arising at base. Pronotum widest before base, convex; anterior and lateral margins convex; posterior angles not acute, anterior angles obsolete. Scutellum wide, triangular, side margins slightly concave. Elytra rather large, quadrate, not concealing apex of abdomen. Prosternal episterna and epimera distinct. Mesosternal process mucronate. Metasternum not attaining sides of body; metasternal episterna very conspicuous. Legs moderate, posterior rather small; anterior and intermediate coxae almost globular, contiguous, posterior subtriangular, remote. Tarsi equal, claws normal. Abdomen with six visible ventral segments.

This genus differs from *Trichopteryx* in having 9th antennal segment scarcely larger than 8th, pedicel narrower than scape, posterior angles of pronotum not acute, elytra expanded at apex, metasternal episterna very conspicuous and sharply out of plane with metasternum and extending some way over coxae. The posterior coxae are smaller. Also in the genotype species the eyes are smaller and set more outwards, more easily visible from above, and the apex of abdomen is faintly quinque- instead of tri-spinose.

Genotype, the following species.

NEOTRICHOPTERYX GRANDELYTRA, n. sp. (Text-fig. 17.)

Chestnut-brown, nitid, finely and irregularly punctate, pubescent. Head light-brown; punctures very fine and close; hairs short and sparse. Eyes black. Antennae: scape and pedicel lurid, flagellum stramineous. Pronotum with a very fine pattern of punctation or honeycombing superimposed by coarse irregular punctures; hairs pointing in all directions. Elytra dark-brown, except at edges, especially apices, which are almost lurid and diaphanous; the fine punctation almost obsolete, the coarse punctures pronounced; hairs, although irregularly planted, are all pointing backwards; apices of elytra broad, posterior margins forming an obtuse reentrant angle. Legs lurid. Ventral surface of body light-brown, except metasternum and its episterna, which are ferrugineous. Length, 0·82 mm.; width, 0·42 mm.

Habitat.—Lord Howe Island (summit of Mt. Gower; A. M. Lea).

Type in South Australian Museum, cotypes in Colls. Lea, Deane, National Museum.

PTILIUM TORRESENSIS, n. sp. (Text-fig. 18.)

Elliptico-rectangular, widest across elytra, somewhat depressed, scarcely opaque, pubescent, brown. Head rather long, widely rounded in front, pubescent, hardly nitid, dark-brown. Eyes rather small, black. Palpi maxillary with terminal segment long, slender, faintly curved; segment 3 subspheroidal. Antennae rather short, 0·42 of length of body; scape normal to rather large, pedicel narrower, tapering to apex; 3 to 8 slender and rather short; 9 large, as large as 10; 11 invert acorn-shaped. Pronotum widest at middle; lateral margins very convex at middle, lightly convex near anterior angles, concave near posterior angles, these rectangular; pubescent, brown. Scutellum normal. Elytra widest just before centre, subparallel, rather broad across apices, scarcely dehiscent; pubescent, brown. Wings: membrane colourless; central vein and hair fringes black. Abdomen completely covering elytra; six visible ventral segments, 4th with a

broad tuft of hairs along centre of posterior margin. Mesosternum with intercoxal process rather long. Metasternum with intercoxal piece broad, widely excavated on posterior margin. Coxae: anterior contiguous, somewhat globular; intermediate contiguous, deeply set, subdepressed; posterior broad, rather distant. Femora: anterior and intermediate broad, posterior small. Tibiae and tarsi medium. Length, 0·6 mm.; width, 0·28 mm.

Habitat.—Murray Island, Torres Straits (A. M. Lea).

Type in South Australian Museum; cotypes in Colls. Deane and South Australian Museum.

Note.—Beetle emerging from chrysalis is on card beside centre specimen (type).

This species differs from *P. simsoni* Matth. in having the ninth segment of the antenna unusually large, being practically as large as the tenth, and thus forming with this and the terminal one a three-segmented club. The head is shorter and the eyes smaller. The base of the pronotum near the angles is not oblique; apices of elytra less rounded and the pygidium not visible from above. The general form is slightly more parallel.

In all the species described herein under the genus *Ptilium*, the form is more parallel and rectangular, the surface more depressed or flat on top and the pronotum wider in proportion, being nearly as wide as elytra, than in the European species of which I have examples, viz., *P. myrmecophilum* Allib., *P. foveolatum* Allib. and *P. trisulcatum* Aube.

Ptilium flavoterminum, n. sp. (Text-fig. 19.)

Elongate, parallel, depressed, opaque, coarsely punctate, sparsely clothed with a fine, very short, white pubescence, walnut-brown, elytra yellow at apices. Head black, large, widely rounded in front, wide at base. Eyes somewhat narrow above, silvery. Antennae clothed with very short hairs, yellow; scape and pedicel darker at apices, scape of normal length, pedicel rather longer; segment 3 short, small, conic, 4 to 7 long slender cylindric; 8 and 9 small, elliptic; 10 and 11 large, ovoid. Pronotum lightly convex, sides evenly curved, anterior angles obtuse, posterior angles obsolete, basal margin convex at centre. Scutellum as long as wide, side margins concave near apex. Elytra subparallel, the yellow colour of apices shading into the main dark-brown about one-fifth from apices, entirely concealing abdomen. Legs light-brown. Length, 0·6 mm.; width, 0·2 mm.

Habitat.—Noumea, New Caledonia (A. M. Lea).

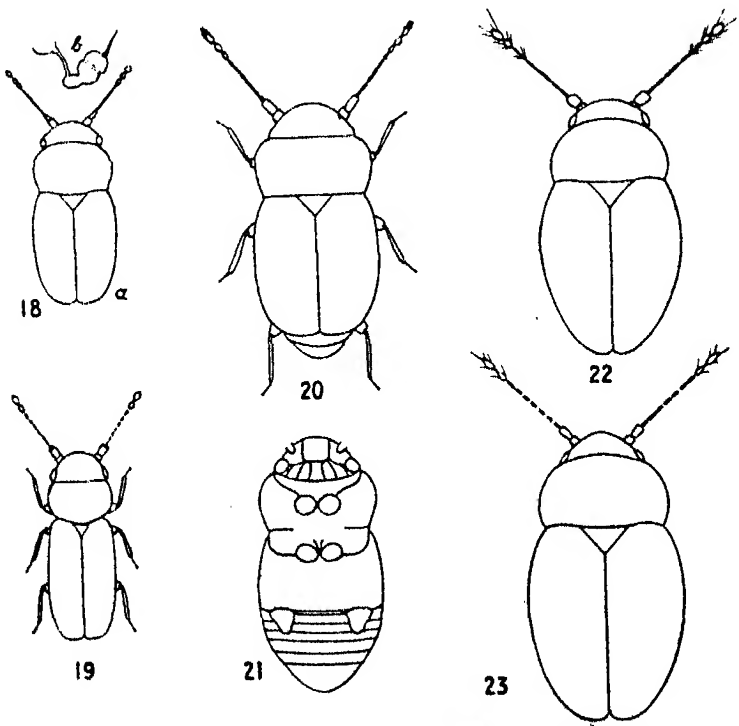
Type in South Australian Museum.

The species differs from *P. torresensis*, n. sp., in being still more parallel, elongate-rectangular. The antennal club is two-segmented as in *P. simsoni* Matth., but the segments are more pointed anteriorly. The head is longer and the hind angles of the pronotum are obsolete. The species is further distinguished by the yellow apices to the elytra. The pronotum is widest at the middle and the elytra are widest at middle, the pronotum being scarcely wider than the elytra.

Ptilium latum, n. sp. (Text-figs. 20 and 21.)

Ovate-quadrate, broad, subdepressed, widest across elytra, bay-brown, lightly setose. Head large, rounded in front, convex, glabrous, nitid. Eyes not easily visible from above. Palpi small, inconspicuous, cream-coloured, terminal segment slender. Antennae not heavily clothed with hairs, flavous; scape large, wider than pedicel; pedicel rather long, narrower at apex than at base; segment 3 small,

obconic; 4 to 7 slender, cylindric; 8 and 9 elliptic, 9 rather larger than 8; 10 ovoid, larger than 9; 11 ovate-elliptic. Pronotum finely pubescent, lightly convex, widest just before middle; anterior and posterior margins straight, side margins concave except near base; anterior angles obsolete, posterior angles right angles. Scutellum deltoid, finely rugose. Elytra quadrate, setose, widest at middle, sides lightly curved, apices broad, apical outer angles rounded, exposing two abdominal tergites. Prosternum with episterna and epimera appearing. Mesosternum with intercoxal process prominent. Metasternum large, attaining sides of body; episterna and epimera invisible; posterior margin lamellate at centre, finely



18.—*Ptilium torresensis*, n. sp. 19.—*P. flavoterminum*, n. sp.
20, 21.—*P. latum*, n. sp. 22.—*Ptenidium hughesae*, n. sp.
23.—*Ptenidium otfordensis*, n. sp.

excavated on lateral portions for reception of coxae. Abdomen with six visible ventral segments. Anterior and intermediate coxae normal, nearly spherical, contiguous; posterior coxae subtriangular, remote. Legs rather robust; posterior tibiae extending beyond apex of pygidium. Length, 0·83 mm.; width, 0·4 mm.

Habitat.—Viti Levu, Fiji Islands (A. M. Lea).

Type in South Australian Museum.

Distinguished from all other species of the genus by its large size, broad form, elytra exposing the abdomen, and the unusual structure of the club of antenna. A notable departure from Matthews' figure, given in his Monograph, presumed to be typical of the genus, is the wide separation of the posterior coxae, a character which in itself is almost universally considered to be of more than specific significance. I have included this species under the genus on

account of its pronotal affinity. The pronotum, however, has the posterior and anterior margins peculiarly devoid of curvature.

PHILAGARICA PARVA, n. sp.

Oval, convex, brown, translucent, smooth, widest near base of elytra, sparsely pubescent, margin entire. Head deeply inserted. Clypeus with anterior margin straight. Eyes normal. Antennae rather short, 0·42 of length of body, 9th segment small, terminal one largest. Palpi with the thick segment irregular shaped, the one preceding greatly swollen at its apex, apical segment rather thick, lightly curved, dagger-shaped; subapical minute, invisible. Pronotum highly nitid, glabrous; lateral margins lightly curved; posterior angles not acute. Scutellum wide in proportion to length, glabrous. Elytra pubescent, tapering. Abdomen acute at apex. Metasternum and first four ventral segments of abdomen dark; metasternum rugose. Intercoxal process acute at apex, sides concave. Anterior coxae large, spheroidal; intermediate small. Length, 0·46 mm.; width, 0·27 mm.

Habitat.—Lord Howe Island (A. M. Lea).

Type in South Australian Museum, cotypes in Coll. Deane.

The species is closely allied to *P. agilis* Deane, from which it differs in having (1) metasternum and first four ventral segments of abdomen black; metasternum rugose; (2) intercoxal process more acute at apex, sides concave rather than parallel; (3) clypeus with anterior margin straight; (4) pronotum with lateral margins less convex; posterior angles not acute; (5) apex of abdomen more acute; (6) antennae with 9th segment very small; (7) elytra more pubescent; (8) scutellum wider in proportion to length; and (9) size much smaller, the largest of the series being much smaller than the smallest example of the kindred species.

PTENIDIUM HUGHESAE, n. sp. (Text-fig. 22.)

Elliptic-oval, widest across elytra, highly convex, nitid, without punctation, mahogany-brown. Head black, nitid, widely rounded in front, easily visible from above, convex, widest across eyes. Eyes black, easily visible from above. Antennae 0·49 of length of body; pedicel large, barrel-shaped; segments 3 to 8 slender, cylindric; 9 slender, torpedo-shaped; 10 and 11 large; hairs or setae on 9, 10 and 11 rather long, black; scape and pedicel light-brown, stem of flagellum lurid, club dark-brown. Pronotum widest a little before base, highly convex, highly nitid, dark-mahogany; anterior and lateral margins convex; posterior angles obtuse, anterior obsolete. Scutellum rather wide, short, indistinct; lateral margins concave. Elytra widest at one-third from base, narrowing to apex; apices rounded, scarcely dehiscent; very convex, mahogany-brown. Wings dark-brown; hair fringes long. Legs light-brown. Length, 0·87 mm.; width, 0·48 mm.

Habitat.—Otford, N.S.W. (per Miss Winifred Kent Hughes).

Type in Museum of Division of Economic Entomology, Canberra.

I have not seen an authentic example of *P. lawsoni* Matth., from New Zealand, but should say from the available literature that the above new species would resemble it in certain features, e.g., size, colour, clothing, and to a slight extent in general form and in punctation; but that it would differ markedly in the antennal club being two-segmented, whereas in Tonnoir's figure in Tillyard's text-book, *P. lawsoni* is represented as having a three-segmented club; also in wider head, slightly sinuous base to the pronotum, and in the apices of the elytra the present new species stands distinct. Moreover the reflexed margin over the eyes

and antennae, attributed by Matthews to the New Zealand form, is scarcely a feature in *P. hughesae.*

PTENIDIUM OTFORDENSIS, n. sp. (Text-fig. 23.)

Widely obovate, widest across elytra, convex, nitid, without punctures, black, sparsely lanate. Head black, nitid, widely rounded in front, easily visible from above. Antennae 0·47 of length of body; pedicel large, obovoid; segments 3 and 4 slender, somewhat ellipsoidal; 5 to 9 slender, cylindric; 10 and 11 large, 10 thickest near base, slender towards apex; 10 and 11 sparsely clothed with bristles; scape and pedicel light-brown, flagellum dark-brown. Pronotum widest near middle, convex, nitid, black; anterior margin faintly, lateral margins more strongly convex; posterior angles obtuse, anterior almost obsolete. Scutellum small, deltoid, indistinct. Elytra rather broad, obovate, convex, widest just before middle, apices rather broad, a little dehiscent; sparsely lanate, nitid, with broad shallow punctures widely separated and irregularly placed. Legs lurid. Length, 0·95 mm.; width, 0·52 mm.

Habitat.—Otford, N.S.W. (per Miss Winifred Kent Hughes).

Type in Museum of Division of Economic Entomology, Canberra.

Differs from *P. hughesae*, n. sp., in form wider, especially at apex of elytra, being almost subquadrate; prothorax widest near middle instead of near base; subapical segment of antenna produced anteriorly; colour somewhat darker; clothing as described.

THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. II.

NERRIMUNGA CREEK.

By FRANK A. CRAFT, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(Plates xii-xiii; four Text-figures.)

[Read 24th June, 1931.]

Foreword and Acknowledgments.

This paper extends the area considered in the first of the series, and embraces an area of country lying to the west of the Shoalhaven River. No physiographic work had previously been undertaken in the area drained by Nerrimunga Creek and its tributaries, but means of communication by means of roads and tracks are good, and only the more dissected parts present any difficulties of access. The writer wishes to thank Mr. and Mrs. G. McKane, of Windellama, for their hospitality during the course of fieldwork. Mr. McKane also acted as guide on occasions, and his intimate knowledge of the country was of great assistance to the author.

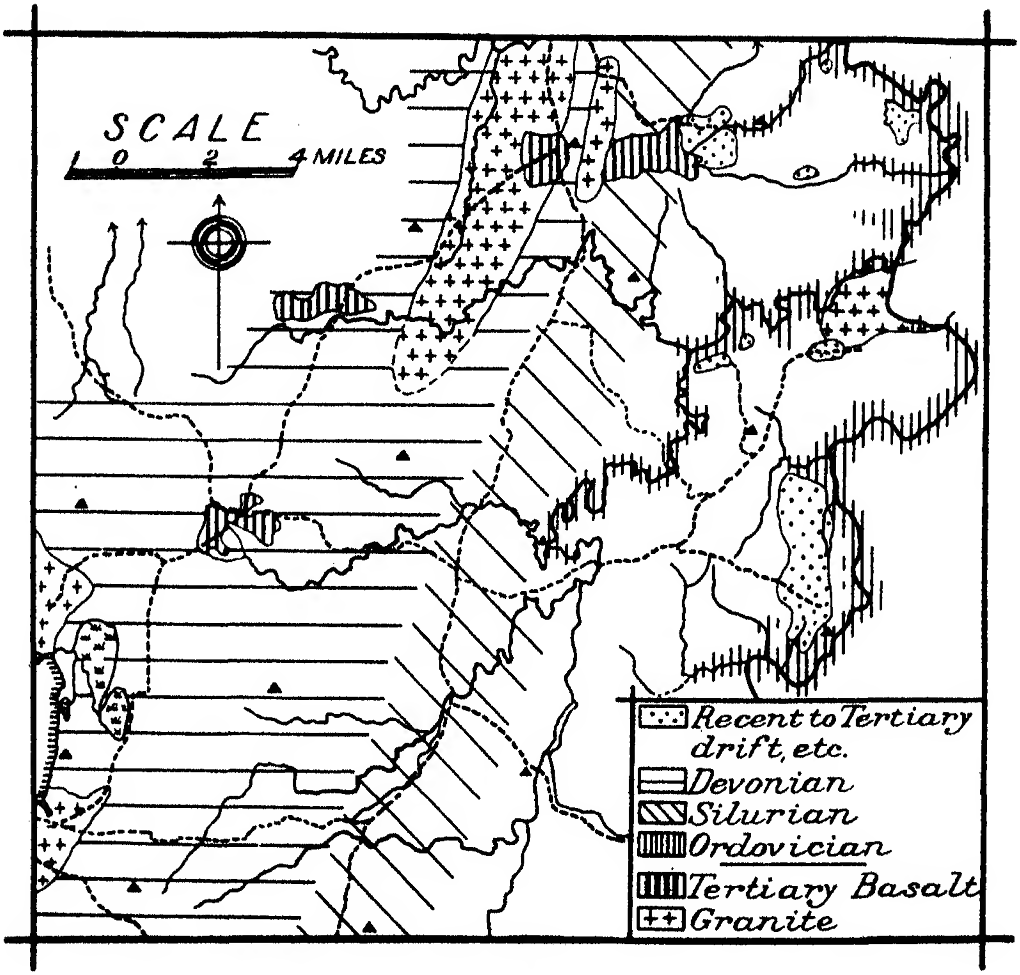
Maps used in connection with the work were given by the Lands Department, and formed an admirable basis for topographic work. The magnetic meridian (declination 9° 35′ E.) is used throughout the paper and, unless otherwise stated, all heights are in feet above sea-level.

Area Dealt With.

The area shown in Plate xiii is some 285 square miles, of which the greater part is drained by Nerrimunga Creek. There is no extensive occurrence of horizontal rocks over this district, which is formed essentially of folded sedimentary and metamorphic rocks which, being closely bedded and well jointed, favour the development of an undulating plain topography in areas of mature erosion. The greater part of the country here considered comes within this class, exceptions being provided by the gorges towards the east and higher residual hills and ridges on the western divide. The absence of the peneplain at 2,200 feet, so extensively developed to the north-east, may be directly correlated with the approximate absence of horizontal strata, and is a characteristic shared by the country further south.

General Geology.

Little is known of the geology of this area, and the boundaries of the various formations have not been determined. Devonian strata are known to exist over its western section, marine fossils of middle or upper Devonian age having been found at Tarago (*fide* W. S. Dun), but their eastern boundary is quite uncertain and they are supposed to grade into strata of Silurian age which, in turn, rest upon highly folded and metamorphosed Ordovician beds. The whole problem is



Text-fig. 1.—Geological Sketch of the Area. The divisions must be taken as broad generalizations only. (After official State map of 1914.)

greatly obscured by great surface weathering in all places except the newly-eroded gorges, and by the accumulation of rock waste over the eastern part of the area. For the purposes of this paper, a general classification can be made under the headings "metamorphic" and "sedimentary".

a. The Metamorphic Series.—The Ordovician beds observed near Tallong continue southward, and their strike swings to 30 degrees east of magnetic north in places along Nerrimunga Creek. In the gorge of the Shoalhaven, erosion has revealed considerable lateral movement so that, for short distances, the strike is almost east and west. The principal rock types observed are grey slates, quartz-schists and massive quartzites. The latter especially are intersected in places by great numbers of quartz veins. At higher levels the highly metamorphosed

character of these strata becomes modified, and bedding and joint planes become more closely spaced, rendering erosion an easier matter.

These strata extend between Nerrimunga and Cowhole Creeks, in both of which there are some fine exposures. On the south of the former stream the rocks of the tableland surface consist of sandstones, shales and, in places, slates, but these are often obscured by surface deposits of clay, sand and grit. It is probable that these relatively unaltered sediments belong to the same series as the metamorphic strata in the gorges, but this is not certain over the whole area involved. (See also Woolnough, These PROCEEDINGS, xxxiv, 1909, pp. 783-84, for a similar case at Tallong.)

Towards the western part of this section of the area, especially along the meridional course of Nadgigomar Creek, a zone of coarse sandstone is found which varies in colour from brown to white and light grey. It is penetrated by numerous narrow and irregular quartz veins, and towards Nerrimunga Creek it would appear to pass directly into the grey quartzites. A similar state of affairs exists elsewhere in the Shoalhaven Valley (see No. iv of this series, on Nerriga district, when published). East of the sandstone a series of white chert is found which forms much of the eastern divide of Nadgigomar Creek. It is suggested that the sandstone referred to is on the western periphery of the Ordovician beds, which underlie newer rocks to the west (Text-fig. 1).

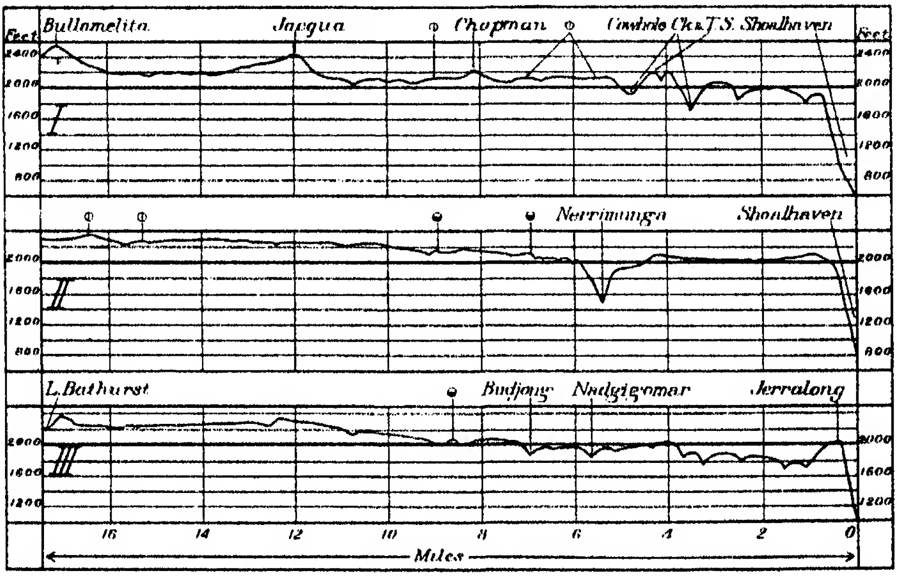
With the exception of a belt of country extending southward past Blanketburn Trig. station, in which the sedimentary strata are in the form of a gentle syncline, rocks in the eastern part of the area dip steeply owing to intense folding. This is especially the case in the lower levels of the gorges. Physiographically, the differential hardness of the various strata is not of first-rate importance, as the hardest occur below the level of the tableland. Greater powers of resistance to erosion have led to the survival of such sections as that forming the Cowhole Trig. station ridge, whilst softer sedimentary rocks on the tableland surface have weathered deeply, and have been subjected to considerable local erosion in places.

b. The Sedimentary Rocks.—About the line of the Bungonia-Windellama-Mayfield road a considerable change in the rocks and in the appearance of the landscape is noticed. The generally barren and rough topography towards the east gives place to smoother undulations extending westward towards the Shoalhaven divide on that side. The streams flow in wide, gentle valleys, which are constricted where bands of harder rocks cross them.

Commencing from the east, we find a series of shales (partly altered to slate) and sandstones. On Windellama Creek, to the north-west of Minshull Trig. station, for instance, a fine-grained brown micaceous sandstone is found, which may be noted again on Jacqua Creek some 15 miles to the north-north-east, near Leakfield Trig. station. In this part a considerable folding is in evidence, but proceeding westward a more uniform westerly dip is noticed, which varies from 30 to 90 degrees. Shales, fine sandstones and more occasional quartzites form the bulk of the rocks, and limestones have been found at intervals. Of the latter, some have been identified as of Devonian age, whilst those towards the eastern side are set down as Silurian (Carne and Jones, *Geol. Surv. N.S.W., Min. Resources*, No. 25, 1919). The eastern limestone at Windellama beside the Bungonia-Mayfield road would appear to be a continuation of the beds at Bungonia. The strike of the former is 30 to 35 degrees east of north, and they swing over to meet the meridional strike of the Bungonia beds towards Inverary Park. The chances are,

then, that a belt of Silurian strata occurs over the Ordovician, but the fact would not appear to have any considerable physiographic importance.

Towards the west of the area, hardened sandstones and quartzites have offered considerable resistance to erosion, with the result that a series of monadnocks is found near the western divide, of which the most prominent points are occupied by the Trig. stations of Percy (2,723 feet), Bullamelita (2,586 feet), and Jacqua (2,433 feet). Between the first-named and the remainder the divide passes over a wide col (Text-fig. 3), part of which has been covered by Tertiary basalt. Further to the west, very considerable erosion of softer strata has led to the formation of the plains of Lake Bathurst and Goulburn, which have the heights west of Mulwaree Creek as a western boundary.



Text-fig. 2.—Profiles across the Shoalhaven Plain. The lines are shown on Plate xiii. i. Includes residuals and the higher northern section. ii. Includes the northern divide of Windellama Creek and part of the southern divide of Nerrimunga Creek. iii. Shows the lower southern section in the region of greatest stream activity. Tertiary basalts and bauxites are indicated. Vertical exaggeration = 8·8.

Thus the western part of the area consists of rocks which are soft or only of a moderate resistance to erosion, varied in the west by harder strata. A general westerly dip of the order of 45 degrees has inhibited the formation of pronounced asymmetrical surface features, and extensive weathering, apparently carried on over a long period of time, has resulted in the accumulation of a thick layer of rock waste on the gentler slopes, and the general breaking up of the harder rocks of which the hills and ridges are composed.

c. *Surface Deposits and Residues.*—The effects of late Tertiary vulcanicity may be observed in parts of this area, and take the form of local basalt flows, dykes, bauxite deposits and surface beds of contact quartzite. Of the first-named, there

are four areas of some size (Plate xiii), the lava having generally been poured into shallow valleys on surfaces of low relief. Dykes are exposed principally in the gorges, the most notable being in the neighbourhood of Jerralong Trig. station, where the weathering basalt gives smooth slopes to the river (Plate xii).

A number of the deposits of pisolitic bauxite occur on hills away from any known basalt flows, and the most striking occurrences near the Bungonia-Mayfield road stand up as mesas of small extent (Text-fig. 3). Other occurrences are on the top of or beside basalt flows, examples being found on the Goulburn-Windellama road and above Jacqua Creek. Other small occurrences besides those marked on the map may exist, as the country on which they might occur is forested, and the deposits may occupy small areas on the bushy ridges. The height above sea-level of those observed agrees with the limits of basaltic occurrences, varying from 2,050 to 2,150 feet. Their physiographic value lies in giving a clue to the amount of erosion which has occurred in adjacent stream beds since their formation (Text-fig. 3), and the occurrence of bauxite deposits in close proximity at different elevations on the northern divide of Windellama Creek probably indicates that all are not of precisely the same age of formation.

In considering other surface deposits, mention may again be made of the thick mantle of rock waste found in most parts of the area. There are also water-borne deposits of considerable physiographic significance occurring within definite vertical limits in the eastern part of the area, and on the higher levels of that part of the tableland there are drift sands and contact quartzites.

Clays are found to a depth of a hundred feet or more in the drainage areas of Jerralong and the southern Spring Creek. They are whiter and more pure towards the lower limits, whilst the upper layers are impregnated with iron oxides and even contain layers of ironstone. These clays lie between ridges of sandstone whose joint planes and fractures have been indurated by a secondary deposit of limonite. The clays have been considerably eroded to form valleys of a rounded section (Text-fig. 2; Plate xii). The clays are derived from weathering *in situ*, and in part are covered by drifts of sand.

The sand drifts are found to the east and south-east of Nadgigomar Creek and in the vicinity of Jerralong Trig. station, where they comprise the drift marked by lighter dots on the map, Plate xiii. The sands are white or grey, depending on the amount of vegetable matter which they contain, and consist of angular quartz fragments at a general altitude of 2,000 feet, although in places there is a considerable thickness (Text-fig. 4). Similar stretches of sand extend southward past Oallen ford, on the Windellama-Nerriga road, and in the present case the derivation might have been from south or west. Associated with a sandy surface about the 2,000-foot level is a series of glassy grey contact quartzites, the principal localities being shown in Plate xiii. Dr. W. R. Browne very kindly examined some of this material under the microscope, and reports it to be identical with the quartzites developed at the contact of late Tertiary basalts at Tallong, and undoubtedly of a similar origin. Further reference is made to it later in the paper.

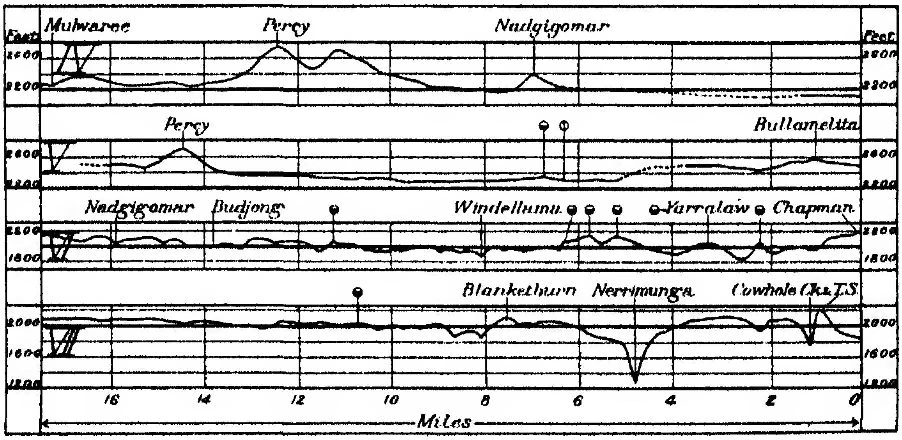
Deposits of surface grit and conglomerate are found extensively over the eastern part of the area, and where the occurrences are of any magnitude horizontal bedding is readily noticed. In the Inverary sector there is a thickness of 220 feet of conglomerate, sandstone, sandy shale and grit overlain by basalt; at Yarralaw Trig. station a thickness of 50 (?) feet of grit is overlain by bauxite; in the drainage areas of Windellama and Nerrimunga Creeks ferruginous grits and

conglomerates are widely scattered about the 2,000-foot level, whilst pebbles of grey quartzite and white reef-quartz are found in the neighbourhood of Manton Mine and Black Springs Creek. All of these are associated with the uplands, and their position on a highly-developed surface of erosion or peneplain, together with the position of some above deep gorges, puts them back definitely to the pre-canyon period. The actual or implied association with late Tertiary basalts gives much of this surface material a late Tertiary age at the latest.

In addition to these deposits, channels filled with stream drift occur to the east of the area. On account of their physiographic importance these can be considered in some detail when the nature of the Shoalhaven Plain is dealt with.

Topography and Physiography.

a. The Inverary Sector (Text-figs. 2 and 3; Plate xii).—The strip of country lying to the north of Inverary Creek consists essentially of two levels. The western portion rises above 2,100 feet, the highest points being the Trig. stations of Leakfield (2,191 feet), Chapman (2,204), Cowhole (2,204) and Inverary (2,164). The points rise above a dissected plain, and the three first-named owe their elevation to the more resistant character of the sandstones of which they are composed. Inverary is on a thin local basalt flow, whose maximum thickness does not much exceed 100 feet. The flow filling an ancient valley near Chapman Trig. is of a rather similar thickness.



Text-fig. 3.—Profiles of the Divides and the Shoalhaven Plain. The lines are shown on Plate xiii. iv. Extends WNW. to Mulwaree Creek and Tarago, and embraces the southern divide. v. Shows the western divide. vi and vii are longitudinal profiles of the Shoalhaven Plain. Tertiary basalts and bauxites are indicated. Vertical exaggeration = 8·8.

An outlying effect of the Inverary flow is a bauxite knoll to the north of Cowhole Trig. at 2,140 feet. According to the report of local miners, the bauxite is more than a surface capping, but the mesa structure indicates a previous higher level for the surrounding country. Hollows in the contorted strata near Cowhole Creek are filled by horizontal conglomerate, grit, soft sandstone and shale. The lowest of these beds are at 1,900 feet, and the highest rise to 2,150 (?) feet,

the best exposures occurring on Cowhole Creek and to the north of Washedaway Creek. In the former case, the beds are of light brown pebble conglomerate containing pebbles of quartz and quartzite up to 12 inches in diameter, and associated with light sandstone. The thickness of the phase is 40 feet, and the conglomerate is hard and massive. Above this are beds of friable sandstone and shale, the whole being overlain in part by the Inverary Park basalt. Pebbly clays containing fossil leaves have been found during mining operations under the conglomerate, and there is a strong probability of the beds being of late Tertiary age.

On Washedaway Creek the pebbles of the conglomerate are smaller, and it exists as a massive deposit between 1,980 and 2,000 feet. It is strongly impregnated with iron oxide, which gives a brownish or reddish appearance on weathering. Here again the shafts of alluvial miners have penetrated the clay below the conglomerate, but one does not notice pebbles in the dumps, although pebbles of much-decomposed porphyry are included in the Cowhole Creek clays. These beds contrast with the strata at the base of the Permian Upper Marine Series, which occur to the east of the river at an elevation of 2,300 feet. The latter are white or light-grey in colour, and contain rounded pieces of quartzite, quartz-schist, porphyry and slate set in a fine white matrix. The base rests on unweathered quartzites, sandstones and slates, and has an altogether different appearance from the sediments about the Inverary sector. Altogether there seems to be a clear differentiation between the two.

The second unit of the sector consists of a dissected terrace above the Shoalhaven gorge. It is cut across by Cowhole Trig. ridge, to the north of which is a dissected plain at 1,900 feet drained by the northern Spring Creek. To the south of the ridge the plain is somewhat higher, but falls from 2,100 feet on the west to 1,850 feet above the Shoalhaven gorge immediately south of the mouth of Cowhole Creek. This tract forms an essentially level plain cut across by the level valley of Washedaway Creek flowing 200 feet below its surface, and by the steeper, narrower gorge of Cowhole Creek, whose sides are almost precipitous (Text-fig. 3). The plain surface towards the river in this southern part is strewn with quartz gravel and pebbles between 1,940 and 1,980 feet, whilst ferruginous conglomerate overlooks the junction of Cowhole Creek with the river from 1,850 feet. Much of this material has been worked for gold, of which a little has been won, but it is simply a surface screening dominated from the east by the higher land across the river (Plate xii), and overlooked by Cowhole Trig. and the higher country to the west.

Thus we find a higher erosion level rising to 2,200 feet, whilst the newer—but still pre-canyon—level is from 1,850 to 2,000 feet. A considerable thickness of horizontal material exists towards the west, but it thins out to a mere screening which covers parts towards the east. It would appear that the lower levels have been cleared of the greater part of the newer material deposited upon them, as the Inverary Park beds have been considerably eroded on their eastern face, and the incoherent material which forms the greater part of such deposits on the tablelands offers no great resistance to erosion. An ancient erosional level based on or below 1,850 feet is indicated, and the basalts preserve a surface—partly of erosion and partly of deposition—at 2,060 feet.

b. The Shoalhaven River.—The general features of this stream have been described in the first paper of the series. Coming upstream from the junction with

Bungonia Creek, a gentle grade is followed through the "block-up", which lies below the mouth of the northern Spring Creek. Here the sides of the gorge rise sheer from the water's edge, and the whole space between them is occupied by a deep river. Above this point the river has moved laterally in places, one result being the abandonment of part of its old channel on the western side above Cowhole Creek, the former section now forming a lagoon, from which the waters of the river are diverted by a great bar of quartzite except in times of high flood. In places the flood terrace is up to 200 yards wide, and is covered with boulders, amongst which Casuarinas grow. Periodical floods destroy these, so only young trees are seen in such places. In other parts both sides of the gorge close in, making it almost impassable. At the mouth of Nerrimunga Creek there is a flood platform of scoured grano-diorite just above the level of the river, which is here interrupted by rapids. The tributary stream has carried huge blocks of igneous rock to the edge of the platform, one piece containing 180 cubic feet, but normally its volume is quite small, and it ceases to flow at times during the hottest months.

Above this point a uniform rise continues; basalt dykes cross the river near Jerralong Trig. station and further upstream (Plate xii), and still proceeding southward there is a steeper section with long series of rapids which lead to the gentler gullies of the tableland about Oallen ford.

The fall line of the tributary streams depends largely upon their catchment area, and only in the cases of Nerrimunga, Cowhole and the northern Spring Creeks, are the tributary gorges of any length when compared with the lengths of the respective streams which have eroded them.

c. *Jacqua Creek.*—This stream heads on part of the higher section of the western divide about 2,500 feet, and also on the basalt flow on the Goulburn-Windellama road at 2,300 feet. Its valleys are mature to their heads, and the stream itself shows well developed meanders and an old profile (Plate xiii). The wider bends enclose areas of level land which comprise a good deal of alluvium and hill-wash resting on pebbles. Passing the second area of basalt the valley widens out until the Bungonia-Mayfield road is reached, where the stream flats attain a width of 600 to 700 yards.

The presence of a bauxite capping on either side of the valley about 2,050 feet shows the extent of more recent erosion in the formation of this broad valley, whose floor is 200 feet below the bauxite. A contributing factor to this result has been the soft nature of the clayey rocks in which the wider parts are found. Proceeding, there is a great turn southward past Leakfield Trig. station. The stream flats have been left, and the stream is slightly entrenched in an undulating surface. A tributary valley in granite to the east of the Trig. station is broad, but it is limited on the east by rough sandstone and chert ridges and in this section the stream falls into a gorge, which deepens steadily to a depth of 500 feet at the junction of the stream with Nerrimunga Creek.

Between Jacqua and Nerrimunga Creeks and Leake's Gully the rough strike ridges persist, although they rise little above the smoother plain of the district, their highest points falling short of 2,100 feet (Text-fig. 3). Glassy contact quartzite occurs on the surface about 1,870 feet, to the north of Leake's Gully, its horizon here being 200 feet below the highest point on the ridges. These are considerably dissected by the short lateral and transverse streams typical of such country, but the valleys of such tributaries as that in Leake's Gully enter

Nerrimunga Creek above the fall line, their junctions are accordant, and the lower parts of their courses more gentle than the upper, which fall sharply from four linear ridges.

Between Jacqua and Windellama Creeks the dividing ridge is broad with slight rises, and gullies fall gently to the main valleys. This part follows the local strike, and consists of sandstones. In part it appears to be a continuation of the Jacqua Trig. ridge, and the hill on which Percy Trig. is situated may be an extension of the same line, although this is not certain, as the intervening plain is level and deeply weathered.

d. Windellama Creek.—This stream flows from the western divide through a broad, mature valley to Windellama. Wide, shallow tributary valleys come in from the northern side, whilst a gentle concave plain falls to it from the south. After crossing the limestone near the Windellama-Mayfield road, the stream passes through a trench 100 feet deep, but emerges into an undulating valley which is followed until the meanders are reached near Minshull Trig. station. Then the stream swings against bluffs of fine brown sandstone, whilst some of the bends enclose level plains. At the junction with Nadgigomar Creek at 1,800 feet a sharp trench exists, and marks the end of Windellama Creek proper, the combined stream being known as Nerrimunga Creek.

A feature of some interest exists by the roadside at Windellama, where a light grey sandstone associated with the limestone is found to have been silicified to a glassy quartzite. This follows the strike of the sandstone, and the lower limit of the altered zone is found by the roadside at 1,960 feet. The alteration was doubtless effected from a slightly higher level, and probably represents one result of the late Tertiary lava flows.

e. Budjong Creek.—This is, perhaps, the most interesting stream of the Nerrimunga drainage system, as its drainage area embraces the most varied topography. It rises in the hardened sandstones at Percy Trig. station, and flows for a short distance over gently-falling plains about 2,300 feet. Here it is a strike stream, but passing eastward from the influence of the high country, its course lies through a mature valley, where it is joined by Conner's Creek (the first from the left), about 2,000 feet, the latter also coming from a mature landscape. The deeply weathered and gentle slopes about this junction are smooth and clear and of a clayey nature, but near the Windellama-Mayfield road the valley narrows as it crosses harder sandstone and quartzite, and a bank on the left side rises 100 feet above the stream.

Passing the road at 1,930 feet, these conditions of topography continue into slates and sandstones, with very gentle slopes on the right side of the stream lying opposite the higher left bank. Above the junction with Nadgigomar Creek is a great "S" bend representing a somewhat incised meander. Against the first part of the "S" at 1,850 feet there is a low divide to the north only 40 feet above the stream; this divide and the slightly higher ridge continuing eastward are covered with pebbles, which have been cemented on the higher levels to form a ferruginous conglomerate, and probably represent Tertiary drift with no immediate connection with the modern stream. There are also occasional patches of glassy contact quartzite on this ridge, but more notable occurrences are found northward across the next small stream, where they occur about the 2,000-foot level.

The second part of the "S" encloses an ironstone knoll rising to 1,970 feet, but across the stream a gentle plain is lower. Budjong Creek is swinging

against the outer bends and is removing a flood terrace some 15 feet above summer water level. This alluvium rests on a soft planed-off terrace of sandstone and slate. Looking up the valley from the eminence referred to, it is seen to be broad and to lie very little below the level of the eastward-falling plain, which rises evenly on to the low western divide to the north-east of Percy Trig. (Text-fig. 2). Further east the ridges show a very even skyline from 2,000 to 2,050 feet, although a false appearance of height is given by the slopes leading up from Nadgigomar Creek. Budjong Creek falls into Nadgigomar Creek through an undulating valley.

f. Nadgigomar Creek.—The head of this stream is in the hills near Percy Trig., and its upper course lies in an early mature valley down the slopes. On approaching the Windellama-Mayfield road the valley widens, and more extensive alluvial flats up to 300 yards in width appear. Continuing downstream, the creek is found to flow with a gentle fall from 100 to 150 feet below the surface of the plain. This section is found in more resistant rocks than is Budjong Creek, so the valley is narrower and the flats more restricted. Gentle slopes and occasional wide tributary gullies lead down from the adjacent level plain on either side.

Wider alluvial flats are found above the Nerriga road up to the northward bend, but below the road the higher plain again closes in, and the valley narrows. In this section the grade is slight, and an old dam built for a mining water supply still holds back a considerable body of water. At the dam site an old channel has been exposed by recent erosion, and Tertiary quartzite is found as low as 1,910 feet, apparently transgressing the drift area (Text-fig. 4). The eastern ridges continue to rise from the water's edge, but near the dam on the west is an extensive level patch of sand drift.

The gentle fall of the stream continues, and once again the higher plain approaches from the west, to retreat in a series of gentle undulations as Budjong Creek is approached. The eastern ridges are also considerably eroded. Tertiary quartzite continues along the valley at intervals, generally being 50 feet above the modern stream, and the junction of Budjong Creek is marked by flats at 1,850 feet which contain rounded pieces of this material. Below here the valley again narrows in sympathy with harder strata, although the grade is still slight.

Passing the eastward road from Windellama and turning westward towards Minshull Trig., the left side is fairly steep and the right, though much gentler, is sandy and very barren. The trench at the junction with Windellama Creek has already been noticed, but immediately below the junction on the right side a limited flood terrace is found at 1,810 feet—some 15 feet above the stream. From the grade of the stream and the topography of the valley which it has eroded, it will be seen that a mature valley has been carved in a plain surface which falls gently eastward, the width of the valley and the gradient of its sides having been conditioned by the resistance to erosion of the strata concerned.

g. Nerrimunga Creek.—The course of the main stream falls easily and naturally into two sections according to its gradient (Plate xiii). For the first 4½ miles the stream flows in a trench 200 feet deep cut in a sensibly level stretch of land. For the greater part of this distance the creek is wide and deep, but the slight fall between reaches is marked by rocky stretches of channel. At the junctions with small tributaries there are restricted areas of undulating valley topography, but elsewhere the sides of the valley are steep, as the tributaries have selected the softer strata in eroding their courses, whilst resistant meta-

morphic rocks occupy the intervening sections. Below Leake's Gully the sides close in notably and are precipitous in places, but the stream flows gently in a channel up to 40 yards wide until the steeper fall is commenced.

When this event occurs, the trench is left and a characteristic "V"-shaped gorge entered, through which the stream falls uniformly to the Shoalhaven. The maximum depth of the gorge is 1,200 feet, and it is marked by deeply entrenched meanders. Slopes on the concave sides are steep and, as the rocks are highly inclined and well jointed, loose scree is common and landslides occur. The convex sides fall towards the creek as longer and gentler peninsulas. The only tributary gorge of any length is that of Jacqua Creek, which flows over bars of massive grey quartzite in entering the main stream.

Above the gorge there are terraces between 1,800 and 1,900 feet above sea-level, on which ferruginous grit, sand, Tertiary contact quartzite and water-worn pebbles are found. Away from this irregular terrace—which is not developed near the river—the land rises to rough ridges on the north-west, but is gentler to the south, where sandstones and softer slates are more in evidence.

Taking Nerrimunga Creek and its tributaries as a whole, certain general features stand out clearly. The streams have cut shallow, mature valleys in an upland plain surface, and have taken advantage of the softer country west of the chert belt in widening their valleys. In this section the rocks have been notably weathered and decomposed in harmony with the general appearance of maturity, but the more siliceous strata further east, although forming a lower surface, contain the rougher and narrower valleys. The most notable of these is the trench in which the first portion of Nerrimunga Creek flows. Differential erosion in the sloping plain is thus important.

The upland parts of the streams, down to 1,700 feet, are beautifully graded, and show profiles characteristic of maturity. The smooth profiles of the lower part of Nerrimunga Creek and the portion of the Shoalhaven involved are characteristic of powerful streams cutting through highly-inclined rocks. Individual waterfalls and cataracts are small, but there is a definite break of slope in the profiles below 1,700 feet.

Parts of three cycles of erosion are shown. The oldest is a small section at 2,300 feet at the head of Budjong Creek; then comes the most extensive, which has been carried to maturity over the area and is based about 1,700 feet. The latest and, at present the most active, is controlled by the existing grade of the river, but the head of erosion is only advancing upstream very slowly on account of the hard inclined rocks being encountered.

All of the larger streams show well developed meanders. Above the junction of Windellama and Nadgigomar Creeks it may be taken as a general rule that present-day conditions favour the extension of the meanders, which are being actively enlarged in many cases. Below this junction, however, the sides of the trench into which the main stream flows are both uniformly steep, especially below Leake's Gully, and no important lateral movement is indicated since the stream began to entrench itself in the terrace above 1,800 feet. The occurrence of pebbles and drift over this higher level demonstrate considerable lateral movement before the erosion of the trench and the gorge below it, so it appears certain that the meanders of Nerrimunga Creek have been inherited from this level with but little enlargement or alteration in plan, although the sloping ridges enclosed by the meanders of the gorge section do not preclude the possibility of lateral extension in the process of downcutting, and a certain amount of which is to be expected.

The commencement of the meanders apparently post-dates the surface deposits of the tableland.

The persistence of old stream lines is indicated by the correspondence of the drift and Tertiary quartzite with the hollows in which modern stream valleys are found. This is especially the case with Nadgigomar and Nerrimunga Creeks, whose general directions are largely pre-basaltic in age, and bear a close relationship to the hard chert ridges. In the case of Jacqua Creek, the presence of grit at Yarralaw Trig. station, together with the associated and neighbouring bauxite deposits all lying within the boundaries of the main valley (although well above the stream), indicate a stable outline for that creek also. The basalt-filled hollow near Chapman Trig. with a base about 2,050 feet corresponds with the bauxites of the valley at 2,050 feet, and may possibly indicate a former stream line leading north-eastward towards Bungonia Creek. The steep fall of the corresponding tributary to Bungonia Creek is unfavourable to the suggestion, which is not supported by the meandering stream line towards Nerrimunga Creek cut indifferently through soft and hard strata.

Perhaps the most significant fact disclosed in the study of these streams is the general mature erosion of the upland section to a local base level somewhat below 1,700 feet above sea-level. If the upland profile of Nerrimunga Creek be continued, it will reach the Shoalhaven about 1,650 feet, which may be taken as the downward limit of erosion in the area previous to the new cycle resulting in the erosion of the canyons. As we shall see presently, the fact is by no means isolated.

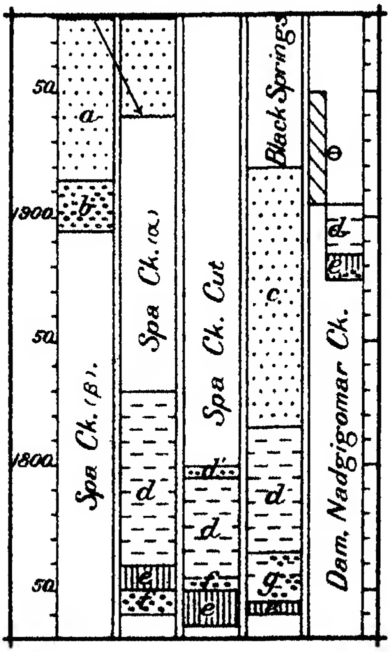
Land Forms.

a. The Residuals (Text-figs. 2 and 3).—The existence of old residuals on the western divide has already been noticed and explained. The massive quartzites noted in the first paper of this series are not developed to any extent in this area, so the high ridges become less in extent and more disconnected as one comes southward from the Bungonia district, until such residuals as Percy and the isolated double hill which forms Nadgigomar Trig. station consist of sandstones which have been locally hardened as a result of igneous intrusions. Even in the cases of the highest points, the slopes leading up to them are not so steep as those found in the residual ridges west of Bungonia, and a great basalt-filled col occurs on the western divide. Towards the east of the area there are several points rising to 2,200 feet, but these would appear to represent locally unweathered rocks which stand up a little above the general even skyline about 2,000 feet. Notable relics of ancient cycles of erosion are virtually confined to the west of the area, and are not extensive.

b. The Shoalhaven Plain.—On the other hand, the Shoalhaven Plain has become a far more important feature than it was further north. Towards the east of the area it has a great extent between the defined limits and 2,100 feet. Towards the west of the area it rises gently, and part of the country in the Inverary sector also rises above the defined upper limit. From the stream grades and general topography (Text-figs. 2 and 3; Plate xiii), it may be inferred that the lower parts of this plain have been produced as the result of normal erosion acting on somewhat higher land which resembled the lower parts of the western divides in altitude. The evidence of a dissected plain was noticed in the discussion of the streams, and the fact stands out clearly from the profiles. In addition the drift, Tertiary quartzite and bauxite deposits all occur within definite limits and from

50 to 200 feet as a general rule above the modern stream channels. Of the many examples observed and charted, the lowest limits of the tableland drift are about 1,850 feet, above Nerrimunga Creek, whilst the general run of them away from this lineament is around 2,000 feet. The quartzites occur between 1,900 and 2,050 feet, with a predominance of those towards the upper limit, whilst the bauxites are found about 2,050 feet, with exceptions rising to 2,150 feet. In addition, the base of the Chapman, Inverary and Jacqua Creek basalts is about 2,050 feet. It may therefore be asserted that the Shoalhaven Plain forms a definite surface of erosion and later deposition at a general level of the order of 2,000 feet above sea-level, and that mature valleys have been incised to 200 feet in this surface.

There is, however, another factor to aid in the elucidation of the physiography of this upland surface. Above the Shoalhaven River, beds of drift containing a little fine gold have been extensively cut away in the process of sluicing, and fine sections of them are now exposed (Text-fig. 4). Mention has been made of the old stream channel exposed near the dam on Nadgigomar Creek and, with the exception of elevation, it might serve as a typical example. Alluvial deposits lie on highly weathered and softened slates and sandstones crossed by beds of unweathered chert, and consist of ferruginous conglomerate overlain by black, laminated peaty clay containing old tree trunks in hollows altered to lignite. Overlying this again is clear white quartz gravel cemented loosely by white clay,



Text-fig. 4.—Sections of late Tertiary Drift. *a*, sand and small pebbles; *b*, large pebbles and conglomerate; *c*, sand; *d'*, surface pebble drift; *d*, quartz gravel and clay; *e*, carbonaceous clay, peat and lignite; *f*, ferruginous conglomerate and coarse gravels; *g*, quartz gravel and pebble beds. See also Plate xii.

and drifted over by brown hill-wash. The wash is roughly stratified and, although Tertiary contact quartzite is present in quantity at a slightly higher level, it cannot be definitely asserted that it overlies the alluvial deposits.

Turning to the east of the area, a similar kind of deposit is found at Black Springs Creek, where a cut some 600 yards long and up to 200 yards wide has been made in it. But whereas the material at the dam has a lower limit of 1,870 feet, that at Black Springs is found as low as 1,730 to 1,740 feet, and lies in a valley excavated in the tableland rocks. Above the finer quartz drift a zone of sand is entered which persists above the head of the workings at 1,820 feet right to the head of the stream. Passing northward over the sandy upland, shafts sunk for short distances at intervals reveal small water-worn pebbles in the sand, and small gullies falling to Spa Creek are eroded in this material.

Spa Creek leaves the line of the deposit in its fall towards the cliffs overlooking the Shoalhaven, but a cut 300 yards long gives a complete section of them. Again the base is about 1,730 feet above sea-level, and the thickness of the deposit in the main cut is 70 feet. The loose pebbles of Black Springs are here replaced by solid ferruginous conglomerate, and the relative position of the peaty clays is found to change. Still continuing northward, a minor cut shows the quartz drift giving place to roughly stratified white clays towards the western section, whilst still further north the deep ground is left and a bed of conglomerate at a much higher level is noticed, again overlain by sand. As with the surface conglomerates of the Shoalhaven Plain, it is likely that the ferruginous cement was derived from the underlying rocks and brought to the (then) surface in solution. Pebbles overlying the deep ground would not be liable to such action, and would soon be swept away in subsequent processes of erosion. The higher conglomerate is also drifted over with white or light grey sand. The main deposit at Spa Creek resembles the occurrence at Black Springs in lying in a valley eroded in the tableland rocks which, for the greater part, form a ridge between the drift area and the gorge of the river, but northward of the place where the creek plunges into the gorge, the stream deposits have been cut off by the gorge side, and overlook the river directly.

The old channel at Nadgigomar dam may be dismissed with one further comment—it gives a further proof of the permanency of that particular stream line, but the occurrence is local and the vertical range affected is not great. On the other hand, the more easterly occurrences involve questions of greater importance, as they cover a vertical range of 300 feet, and occur on the edge of the major canyon of the region.

One of their most striking features is noted more especially at Black Springs, where huge slabs of glassy contact quartzite occur in the basal pebbles. These include fragments of chert and pebbles, and with the exception of the contained pebbles, they are similar to the quartzites at Nadgigomar dam, from which Browne's determination was made. Some of these fragments are up to 4 feet long by 3 feet wide by 1 foot thick, and the edges have been smoothed and rounded. Smaller worn pieces of the fine uniform quartzite are also found here, and in the loose drift above the main cut at Spa Creek. It seems fairly definite that this material is of late Tertiary age, and is from basalt contacts, so the drift areas are newer than some phases of the basalts, at least.

As regards other pebbles a variety of quartz and quartzites is found, together with much-weathered porphyries, and possibly some granite. In shape they vary from subangular to ellipsoidal, and in size from three inches to more than a foot

in (major) diameter. The peaty clays associated with them contain abundant broken plant material, but no good specimens.

It is now possible to sum up some of the relationships of the drift. It has been deposited in a valley—or in valleys—eroded to a modern height of 1,730 feet, and general conditions of relative stillness are indicated in the streams or lake into which the material was brought. At times more vigorous currents brought in pebbles, but the general accumulation was of small material, and in the last stages, when the water was spread out over the widest area, sand derived from the higher levels of the watersheds concerned formed the bulk of the material. Conditions were equivalent to continued subsidence, and the total extent was of the order of 300 feet. Conditions of a rather similar nature have already been noted in the Inverary sector, but extending definitely 50 feet higher, and possibly a little more.

This leaves two major questions—the cause of sedimentation and the origin of the channel or channels in which the deposit is found. For the present, no attempt will be made to answer the first of these, but the second may be considered.

The most likely explanation was propounded to the writer by Mr. G. McKane, who suggested that the Black Springs and Spa deposits lie in a continuous channel which was an earlier course of the Shoalhaven. He instanced the facts that sluicing for gold had disclosed a "run" of gold near the base of the drift which continues towards the modern watersheds without any appreciable change of level; that the pebbles of porphyry in the Spa deposits are, so far as is known, not derivable from the catchment area of that stream, although occurring in abundance further south, and that the size of the pebbles in the drift is more suggestive of a large stream than one such as Black Springs Creek. To the latter one might add that there is nothing to show the quartz pebbles or gold as being of immediately local origin. He also correlated the different exposures, and inferred the constant height of their base—a supposition verified by observation.

Physiographically, the suggestion is sound. The base of the deposits is at a constant level as far as it is exposed, and the respective exposures are in wide channels on the tableland. Even such a powerful stream as Nerrimunga Creek has eroded a valley of much less width about the altitude of 1,700 feet, and one of the features of this drifted valley is the width of its floor. Sedimentation also proceeded above 2,000 feet, which would have left the Shoalhaven free to choose a course over a wide stretch of country (Plates xii–xiii), as the superior heights about Jerralong Trig. station are simply local knolls. Once such a course were chosen, the renewal of downcutting would scarcely introduce factors likely to lead to considerable further change, for although the drift would be easily channelled, the deeply-weathered clays derived from the country rocks would only offer slight resistance to a powerful stream. In any case, the two minor streams now existing in the drifted area have not breached the sands of their divide, and the country immediately south-west of Jerralong Trig. is amongst the clay land.

Thus it appears that, under special circumstances, the Shoalhaven adopted a new course after the sedimentation was completed, but had previously eroded a valley down to 1,730 feet. In any case this was the lowest level reached before the deposition of the sediments, and it may be correlated with the upland course of Nerrimunga Creek, which is based about 1,650 feet. In other words, the plain was developed about 2,000 feet (modern level), and valleys from 300 to 400 feet in depth were eroded in it. The course of the main stream was partially blocked to an increasing extent, leading to local sedimentation. About the same time

basalt was coming gently through fissures and was being poured out on the land surface, affecting the plain principally, and being associated with the upper limits of the sediments. The actual outpouring began prior to the filling of the deeper channels, and it is probable that the deposits of the higher levels about the junction of Windellama and Nadgigomar Creeks can be correlated with the highest stage observed in the neighbourhood of Spa and Black Springs Creeks, and with the deposits at similar altitudes in the Inverary sector. Thus the erosion of channels to the modern level of 1,700 feet, the outpouring of basalt and the process of sedimentation were, broadly speaking, contemporaneous, and all pre-dated the erosion of the gorges.

c. *Comparison with the Tallong-Bungonia Area.*—The physiographic features of the two sections may be directly compared, as follows:

Age.	Tallong-Bungonia.	Nerrimunga Creek.
Ancient	High residuals.	High residuals.
Pre-basaltic ..	Residual level, Tallong, 2,400 feet.	Western divide, 2,400 feet.
Pre-basaltic ..	Peneplain level, 2,200 feet.	——
Pre-basaltic ..	Valleys and plains about 2,000 feet.	Shoalhaven Plain, about 2,000 feet.
Period of flows ..	Erosion of Caoura valley to 1,850 feet or lower.	Erosion of eastern channels to 1,700 feet.
Period of flows ..	? Pebbles and drift of uplands, 1,900 to 2,000 feet.	Drift and sediments, 1,730 to 2,050 feet. (Exception—Inverary Park to 2,150 feet.)
Post-basaltic ..	Mature valleys to 1,800 feet, deepening eastwards.	Erosion of drift—mature valleys of plain, and upper part of Nerrimunga Creek trench to 1,700 feet.
Post-basaltic ..	Erosion of gorges.	Erosion of gorges.

Reference has previously been made to the fact that the basalt-filled Caoura valley was eroded by a small tributary stream, whilst the Shoalhaven apparently flowed at a lower level (Part i), so there is no necessary discrepancy here. The highest of the sandstones at Inverary Park form a purely surface deposit a couple of feet thick in places, but this superficial character is not everywhere certain. The highest of the bedded deposits occur at 2,070 feet.

The connection between late Tertiary channels eroded to the modern level of 1,700 feet and the supposed river capture at Tallong above 2,080 feet is evident, as the surface concerned shows no bending or warping which could account for the downward displacement of the lower channels since the period of basalt flows. On this ground alone it would be legitimate to rule out the idea of capture since the erosion of those particular tableland valleys and, since they antedate the more modern uplift which allowed the erosion of the gorges, the suggested mechanism of capture is not allowable. Thus the conclusions of the first paper of the series are fully justified.

Soil and Water Supply.

Geology and physiography unite in determining the conditions of the soil and water supply. The soils fall into three definite classes: firstly, there are large areas of stony ground in the area, the more dissected siliceous rocks towards the east giving a surface of this type, whilst the higher ridges and divides towards the west are also composed of siliceous types which do not weather readily into soil. In the parts which have been subject to dissection, even over a small vertical range, the slopes are steep, so the general character of this class of country is very dry.

Secondly, there are areas where a considerable depth of clay is found on the surface, or the soils are of a clayey nature. These include much of the valley of Jacqua Creek and the gentler slopes of the valleys west of the Bungonia-Mayfield road, together with the basins of the southern Spring and Jerralong Creeks and the country immediately south-west of Jerralong Trig. station. Country of this type supports the small settlement of Windellama and, since its soil is richer in plant foods than that of the preceding class, it has a considerable value as pasture land, being used for sheep raising. The soil is naturally rather impervious so, with respect to their lengths and the areas which they drain, the streams are of small size and the flow of water even in Nerrimunga Creek is inconsiderable. All of the tributaries cease to flow during the hotter months, but the fact is somewhat offset by their mature form favouring the development of wide and deep reaches which retain water all the year round. In this respect the impervious nature of much of the ground is an advantage. By virtue of it, also, tanks and dams can be built to supply water to stock.

The third soil type comprises the sands and gravel of the drift areas, together with the sandy lands found to the east and south-east of Nadgigomar Creek. Water soaks into this ground readily, but is quickly given up to the local streams, leaving a generally dry surface which is covered with sparse forest and hardy vegetation. This land is of little economic value, but in the isolated case of Black Springs, where it overlies a more compact and impervious drift, a good storage ground for a permanent stream is provided. In general, however, the sandy and drift country is dry and poor.

Isolated areas of particularly rich soil are provided by the larger areas of basalt. In each case the weathering basalt gives excellent pasture land, and a little permanent water comes, in places, from springs under the basalt. These few patches form the best pasture land of the area; the valleys of Jacqua, Windellama and Budjong Creeks are fairly good in general, whilst parts of the valley of Nadgigomar Creek and of the clay region around the head of Jerralong Creek and by the Trig. station of that name are fair. Another isolated area of fairly good land is at Weiramunga Creek, overlooking the junction of Nerrimunga Creek with the river, but there is much almost useless land in the area, including the dissected portions. An exception to this latter remark is found on the western side of the Shoalhaven on either side of Jerralong Trig., where the steep, smooth side of the gorge, with a stiff soil from weathering basalt and slate, has been cleared, although bands of vegetation have been left across the slope in places and on the bottoms of depressions. These have an excellent effect in checking erosion, and provide a welcome contrast to the usual indiscriminate clearing only too frequently practised in such places.

Summing up, it may be said that half of this area is of little value on account of ruggedness or extremely poor soil. Some of this part carries a few sheep, whilst

the remainder of the country is used in sheep raising, and has the reputation of being free from disease and of growing clean wool. Conditions of soil and topography militate against a considerable permanent flow of the streams, but sufficient water is available for pastoral purposes.

Conclusion.

The features developed in the Tallong-Bungonia area are found to extend southward into the Nerrimunga Creek drainage area. The western residuals lose much of their extent, but the Shoalhaven Plain extends notably, and becomes even more important further south. Old channels filled with alluvial material are incised 300 to 400 feet below its general level. In all probability their age is late Tertiary, being the same as that of the basalts, and a similar but perhaps more modern channel eroded to the same level is found in the course of Nerrimunga Creek. The courses of this stream and of the Endrick River, further to the east, are most favourable for the development and preservation of such features, the streams being sufficiently powerful for the former, and yet not powerful enough to carve such notable gorges as that of the Shoalhaven. The physiographic history as developed in the first paper of the series and again outlined in this (see "The Shoalhaven Plain" section) is found to receive substantial support.

EXPLANATION OF PLATES XII-XIII.

Plate xii.

1. View eastward from Cowhole Trig. (2,204 feet), showing the dissected terrace falling to 1,850 feet. The higher country in the background is beyond the Shoalhaven gorge, and is the western scarp of Bulee Ridge. Touga West Trig. (2,409 feet) is the high bluff to the right of the big tree. 2. Hydraulic cut in Tertiary drift, Spa Creek. *x*, bedrock; *f*, conglomerate; *e*, carbonaceous clay; *d*, clay and quartz gravel. 3. The Shoalhaven Plain from Blanketburn Trig. (2,115 feet), looking SSE. The foreground shows erosion in surface clays. The Shoalhaven gorge is in the middle distance, and low on the central horizon is Currockbilly Range (3,700 feet), thirty miles distant. 4. The Shoalhaven River at Jerralong Trig. station, which is the hill to the right. The cleared slopes represent basalt dykes, whilst the high ground on that side is characteristic of a clayey surface, and forms part of the ridge separating the gorge from the Tertiary stream drifts of the tableland.

Plate xiii.

Map of the Nerrimunga Creek section of the Shoalhaven Valley. Form lines are shown in the uplands, and the line at 1,800 feet marks the general fall line to the steep gorges. Profile line iv extends to Tarago. B. Profiles of the principal streams. The sharp drop in Nadgigomar Creek represents the dam, and the part of the Shoalhaven River shown extends from Jerralong Creek to Bungonia Creek. For economy of space, the lower portion has been carried to the left. Vertical exaggeration = 17·6.

THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. III.

BULEE RIDGE.

By FRANK A. CRAFT, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(One Text-figure.)

[Read 24th June, 1931.]

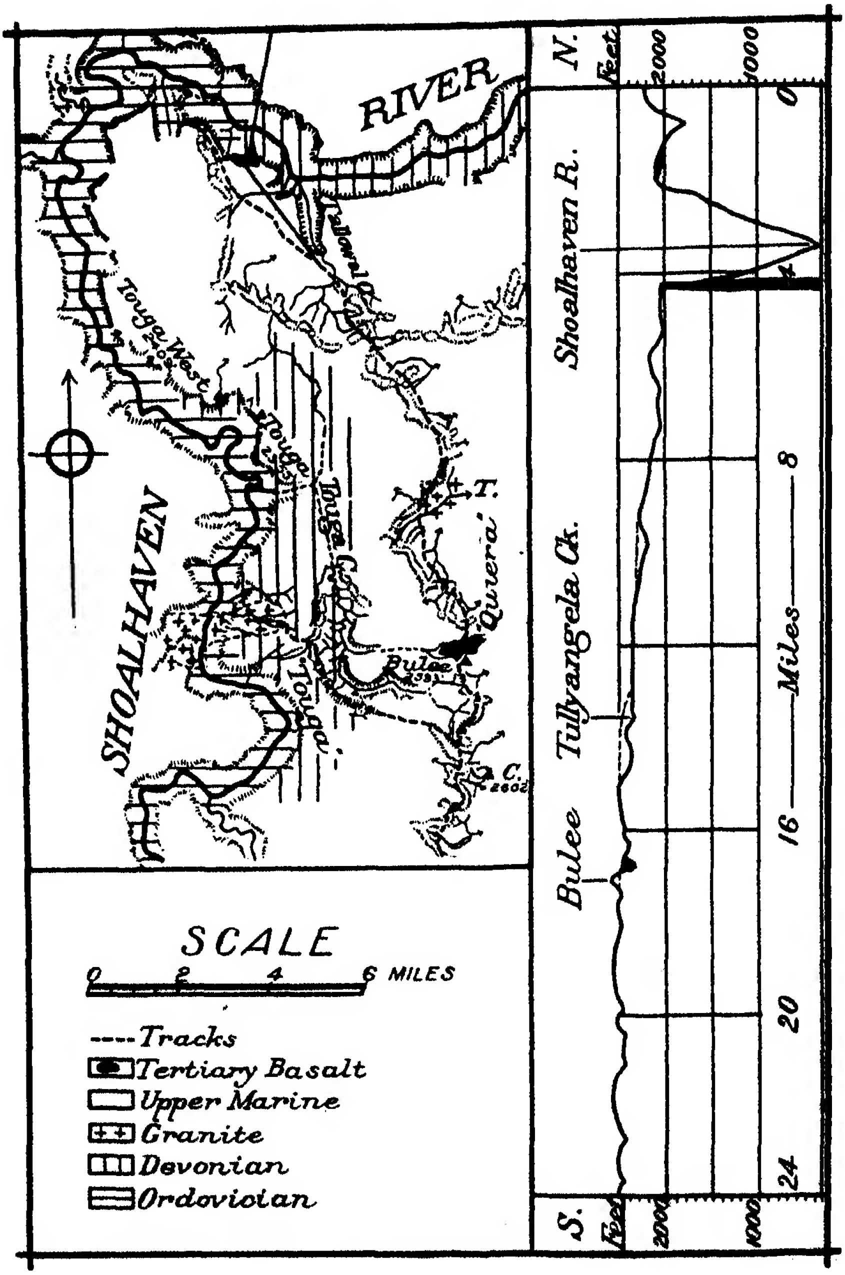
Introduction.

This short paper is the result of a reconnaissance carried out during January, 1931, on the Bulee Ridge, named after a high trigonometrical point in its central portion. On account of its rocky and sandy nature, and the generally dissected character of its surface, this part of the eastern watershed of the Shoalhaven Valley has only been surveyed in places, and much is only accessible on foot by roundabout routes. The traverses on which this account is based were practically confined to the high ridges, and were undertaken to give some definition of the place where the tableland over which the Shoalhaven flows begins to fall towards the coast.

The surface covering of this portion of the tableland consists of sandstones belonging to the Upper Marine Series. These rise from sea-level on the coast to a maximum altitude of 2,600 feet on the ridge here described. Towards the west they thin quickly, and their western periphery has been cut off sharply by the erosion which has produced the Shoalhaven Plain at 2,000 feet. The series consists of whitish agglomerate and conglomerate of a sandy nature containing pieces of various quartzes, quartzites and porphyritic rocks which pass upwards into a white, reddish or light-grey sandstone of a gritty nature. The sandstones contain occasional layers of quartz pebbles and are marked by a massive character with widely-spaced and irregularly-developed joints, of which two sets exist almost at right angles.

The thickness of the series varies from 150 to 400 feet, although in the neighbourhood of Tallowal Creek a thickening to 600 feet is noticed. The altitude of the base varies from 1,900 to 2,250 along the exposed western margin, the former limit being near the head of Touga Creek whilst the latter is at Touga Trig. station. Irregularities in bedding are also noticed, in some cases the bedding planes dipping locally at angles up to eight degrees. These places are exposed by denudation and form bare convex slopes.

Underlying the sandstones are strata of supposedly Devonian age and, along the course of the river, an intensely folded metamorphic series of Ordovician age is found. The former consists of reddish and brown sandstones, shales and slates, but there is apparently no clear differentiation from the older strata, which grade upwards into almost unaltered sedimentary rocks. Nor can a great deal be told off-hand from the degree of folding of the various strata, for intense folding, crumpling and shearing are found mainly within a definite meridional core of the older rocks at the lower levels.



Text-fig. 1.—Sketch-map and Profile of Bulee Ridge. The area covered by the Upper Marine Series comprises the level tableland. The profile line is taken along the road, with minor bends smoothed out. The line north-west and north from Tallowal Creek is the northern section, and the southern end extends 4,700 yards SSE. of the road end on the map to the Nowra-Nerriga road. Vertical exaggeration of profile = 10·6. C = Coolumburra, and T = Tullyangela. The magnetic meridian is used.

Igneous rocks are represented by isolated occurrences of granite, by basalt dykes in the gorge of the river, and by isolated patches of late Tertiary basalt on the tableland. The most notable of these latter is found above the Shoalhaven River near Tallowal Creek, where the precipices are broken by a neck from which lava has been poured on to the adjacent level surface. A beautiful section is now exposed on top of the precipice, and in a nearby small gully the horizontal sandstones have been hardened to a glassy quartzite to a depth of 6 feet.

The topographic significance of these formations is readily appreciated. The hard quartzites and quartz-schists of the oldest rocks are not found on the tableland surface, and they have been cut through by the powerful Shoalhaven River. Where the stream crosses their strike it passes through narrow clefts in immense bars, so it has a turbulent nature in a steep-sided gorge. The massive horizontal sandstones of the tableland surface resist erosion more strongly than the softer and more broken older rocks immediately underlying them, so the gorges and gullies cut through them are crowned by lines of perpendicular cliffs. Weathering of softer bands in the sandstones gives rise to terraces bounded by low precipices, so the surface of Bulee Ridge forms a long, terraced platform.

Topography and Physiography.

Passing northward along the ridge (Text-fig. 1), a sandstone ridge is traversed which varies from 2,400 to 2,550 feet in altitude. It forms the divide between the Shoalhaven River and Ettrema Creek, and in places tributary gullies have been extended right to the ridge by falling streams, giving a series of saddles or cols between which the ridge is higher and more level. Level branches of the main ridge extend from two to three miles east and west, the former ending in the precipices above Ettrema Creek, whilst those in the latter direction terminate in the low escarpment of the Upper Marine Series overlooking the Shoalhaven Plain. Between this escarpment and the gorge sides of the Shoalhaven there is an irregular terrace varying in altitude from 2,000 to 2,300 feet forming, in fact, the eastern edge of the Shoalhaven Plain. In the granite and older sandstone at "Touga" station, these undulations have a width of a mile and a half, and rise from 1,800 feet on the edge of the gorge to 2,000 feet on the east, where there is a sharp rise over 2,300 feet to the ridge west of Touga Creek which is capped with horizontal sandstone, or from which the newer rock has been recently denuded.

Two points rise a little above the general level of the ridge—Coolumburra (2,602 feet) and Bulee (2,593 feet) Trig. stations. Immediately to the north of the latter the ridge consists of a basalt plain at 2,440 feet. The basalt occupies a narrow valley whose floor is 300 feet below the trig. station, and has been attacked with vigour on the west by a stream which falls quickly into a rough gully, and eventually unites with Touga Creek. Gentler valleys lead eastward, but they also give place to walled-in gullies. In other places to the east of the ridge streams head in boggy flats on the sandstone terraces, across which they fall gently for the first part of their courses.

Proceeding north of the Quiera basalt, a rough ridge leads to the head of Tullyangela Creek. The crest is at 2,500 feet, but terraces fall on the eastern side from 2,350 feet. The first part of Tullyangela Creek is in a gentle granite valley at 2,300 feet almost surrounded by low sandstone cliffs. On the opposite side of the ridge the gully heads are also gentler than usual, but the rough gorges are soon reached in either direction.

Up to this point bare rock terraces of slightly uneven sandstone form part of the ridge top. These also continue a little to the north of Tullyangela Creek, but the ridge falls to 2,300 feet, and level depressions lead over its surface and, being filled with a thin deposit of peaty soil, the hitherto bare rock terraces give place to areas of heath and coarse meadow. Rain falling in such places either runs off gently or is absorbed by the spongy soil to be given up eventually by evaporation. Thus the forces of erosion on this section of the ridge crest are very slight indeed.

Gentle valleys are here excavated to a depth of 150 feet below the ridge crest. The most notable fall to Ettrema Creek, here five miles distant, whilst the western fall to the main gully is only two miles long. The Bulee Ridge properly ends where the northward fall to the Shoalhaven gorge begins, and where very gentle sandy slopes lead to the edges of the precipices. These vary in altitude from 2,000 to 2,100 feet, and the southward rise is gently concave. Small swamps are found on the slope, which is covered with a thick mantle of sand, although level areas are grassy. Otherwise the vegetation is a sparse forest or scrub. Immediately above the cliffs the streams flow through short gullies 50 feet deep, and the cliffs have receded along their courses to form bays in the main gorge side.

Passing from Tallowal Creek towards Touga West Trig. station, a gentle plain between 2,150 and 2,200 feet is crossed whose surface is largely covered with acacia scrub. Where the horizontal sandstones exist, the fall to the gullies is marked by low cliffs, but the gullies are mainly cut in older rocks and are extremely wild and steep-sided. The principal fall is to Touga Creek through unsurveyed country, the river eventually being met about 650 feet above sea-level. The area occupied by Touga and Touga West Trig. stations forms a high bluff falling directly to the river. Only to the south do the lower terraces exist on the eastern side of the gorge.

Mention has been made of the basalt neck near Tallowal Creek. Although the modern extent of the flows in its vicinity is not considerable, a great deal must have been swept away in the erosion of the gorge, and there may have been a considerable extent of basalt in the pre-gorge valley of the Shoalhaven.

Soil and Water Supply.

Many of the salient points of the soil and water supply relationships of the ridge will have been deduced already. The horizontal sandstones are almost impervious, so the ridge itself, with only a thin mantle of sandy soil, is dry and barren. In the areas of older rocks there is a great deal of steep and rugged topography, so the sandy and light soils formed from their weathering are easily washed away, leaving crumbling and rocky slopes exposed which are held together by scrub and sparse forest. Thus the siliceous rocks of the area give rise to sandy soils—thin both in the uplands and on the gorge sides. In the former instance, the strong westerly winds of winter sweep the ridge crest, and allow a rather thicker screening of soil on the eastern slopes, but the natural deficiency in plant foods is reflected in a poor vegetation.

Exceptions to the general rule comprise the small areas of basalt and granite, and the sandstone part of the levels at "Touga" station. In the latter case there is an accumulation of soil on the older topographic features, a condition which also prevails on the level stretches near Tallowal Creek. These are the only parts of the area which are of much use: they support a few sheep.

As regards water supply, mention has been made of the swamps due to accumulation of water in the soil and humus resting in hollows on the sandstone terraces. Streams rising from these limited sources are not permanent, although to the south and south-east where larger swamp areas are found they provide water all the year round. Springs occur at the base of the basalts and there are streams in the granitic areas of "Touga" station and Tullyangela Creek, but the general dryness of the country can be gathered from the fact of Touga and Tallowal Creeks ceasing to flow during the warmer months. Topography, soil and water supply all militate against settlement in the area, and people only live permanently on "Talwong" station, by Tallowal Creek.

Summary.

The Bulee Ridge forms a level tableland in horizontal sandstones and extends to the beginning of the coastal fall in the vicinity of the meridional Ettrema Creek. The coastal fall has an average angular value of one degree. The ridge rises gently from north to south and forms a straight, stable divide for the eastern section of the corresponding portion of the Shoalhaven Valley. Streams on the coastal slopes to the east also fall to the Shoalhaven River, but are clear of the tableland proper.

The basalt of Quiera indicates late Tertiary erosion on the ridge down to 2,300 feet above sea-level, whilst similar but higher cols along the ridge make similar processes extend to the present day. It is probable that the basalt does not occur on the original ridge crest, but a little to the east or west of it, as it appears to occupy a very level valley. The higher country corresponds with the extent of the horizontal sandstones, which have exercised a definite protective influence whilst the Shoalhaven Plain has been eroded in older strata immediately to the west. The nearest comparable heights to those on Bulee Ridge are found at the head of Windellama Creek, on the western side of the Shoalhaven Valley, the whole country between having suffered extensive denudation.

The eastward turn of the Shoalhaven River is clear of the higher part of the ridge, and a wide upland depression about 2,000 feet above sea-level has been trenched by the modern gorge. Physiographically the ridge is notable as forming a stable divide on the eastern side of the meridional course of the Shoalhaven, and protecting the Shoalhaven Valley from the destructive erosional influences of the coastal slope.

ON A NEW BOPYRID PARASITE FROM THE COAST OF NEW SOUTH WALES.

By WILLIAM J. DAKIN, D.Sc., F.Z.S., F.L.S.,
Professor of Zoology, University of Sydney.

(Plate xiv; nine Text-figures.)

[Read 29th July, 1931.]

This new genus and species of a Bopyrid parasite is represented by ten females and four male specimens. A much greater number might easily have been obtained, for considerable numbers of the host—a prawn of the group Penaeidae—have been caught by trawlers off the coast of New South Wales, and practically every prawn of the sample obtained for examination* is parasitized. The host prawn has, up to now, been regarded as rare; it is certainly so in collections, but as it is a species found in deeper water and not one of those which regularly invade the estuaries it is probably much more abundant than has been recognized.

Genus CRASSIONE, n. gen.

The genus may be described as follows: A Bopyrid parasite allied to the group *Orbione*, *Parapenaeon* and *Epipenaeon*, the type species being an ectoparasitic branchial parasite under the branchiostegites of a Penaeid prawn of the genus and species *Aristeus foliaceus*. The sexes are dimorphic. The body of the female (Plate xiv, fig. 1) is oval in shape, the greatest width being about midway between the anterior and posterior extremities. The anterior end is broad, the posterior end triangular ending narrowly. The body is asymmetrical but either the one side or the other may be reduced—in other words there are "left-handed" and "right-handed" specimens. The head is distinct from the thorax. It bears a well developed frontal lamina. No eyes are present. The thoracic segments are distinct and the pleural lamellae† of all the segments are well developed. On the highly developed (or non-reduced side) they have the form of broad plates, as in *Orbione* and its related genera *Epipenaeon* and *Parapenaeon*. The incubatory cavity is completely closed.

The abdomen of the female is small, only one-fifth the length of the animal. The somites are clearly defined, including the last or sixth, which is somewhat small. All are visible dorsally. Pleural lamellae are developed only on the first five abdominal segments. Five pairs of biramous pleopods are present and in addition the uropods are also biramous. The abdominal pleura, the pleopods, and uropods all bear tubercles and tend to resemble each other. The only known species is of considerable size amongst Bopyrids, the length of the females reaching 15 millimetres with a breadth of 10 mm.

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* Many were apparently eaten by the trawler's crew.

† Also called pleura and epimera by various authors.

Male (Plate xiv. fig. 2).—The body is much smaller than the female and has the general characters of the males of *Epipenaeon* and *Parapenaeon* species. Eyes are absent. The thoracic segments are distinct and their lateral margins rounded. All the abdominal somites are fused to form one mass and no trace of pleopods or uropods is to be found.

Genotype.—Crassione aristaei, n. gen. et sp.

Note on genus.—There is a small and well defined group of Epicarid parasites restricted to prawns of the group Penaeidae. Up to the present they fall into the genera *Orbione* Bonnier; *Parapenaeon* Richardson; *Epipenaeon* Nobili; *Gigantione* Kossman; and *Orbiomorphus* Richardson. There is a very general resemblance between the genera, more especially in the character of the female thorax. To distinguish between them one has to take the female abdomen as a guide. And even in this criterion there is confusion. The differences as accepted at present (by Nierstrasz and Brandis, and by Chopra) may be set out as follows:

1. Only five abdominal segments visible in the female.
   - (*a*) Pleural lamellae on the five segments all well developed. Uropods biramous .... *Epipenaeon*
   - (*b*) Pleural lamellae not so well developed and only on the first four abdominal segments. Only four pairs of pleopods ...... *Orbiomorphus*
2. Six abdominal segments visible in the female.
   - (*a*) Pleural lamellae present on all six abdominal segments. Uropods uniramous .... *Orbione*
   - (*b*) Pleural lamellae present on five abdominal segments only.
     - Uropods uniramous .... *Parapenaeon; Gigantione*
     - Uropods biramous .... *Crassione*, n. gen.

The confusion has arisen through two notes by Miss Richardson; one rather unexpected statement in 1910 was to the effect that the uropods of *Parapenaeon* were biramous. She herself had previously named and described this genus in 1904 and diagnosed the type species as having uniramous uropods. This position does not appear to have ever been properly cleared up, but Nierstrasz and Brandis not only found Miss Richardson's species in the Siboga collection but another and new species, and as these authorities affirm that the uropods are really uniramous (as first described) the matter must stand at that, at present.

The other and perhaps still more serious statement refers to the genus *Orbione*. Both Bonnier and Nobili used the uniramous character of the uropods as an essential feature in the diagnosis of this genus. Miss Richardson said, however, that the uropods were biramous and contradicted Bonnier. Chopra refuses to accept her view, but it is of great interest, for it may be taken to indicate a difficulty in the interpretation of the last abdominal segment and its appendages. Unless, however, Miss Richardson is correct and Bonnier, Nobili, Chopra and others wrong, there is no doubt that our genus differs from all the others in having abdominal pleura on only five segments with six segments present, and biramous uropods on the last. It is advisable in this connection, to point out the following facts: The abdominal pleura become increasingly large as one passes posteriorly and at a casual glance the last segment, the pleo-telson, might appear to have pleura agreeing in size and general form with those of the preceding segment (the fifth). If one did interpret the almost terminal processes as pleura it would of course be necessary to conclude that the uropods were uniramous, and we should then have agreement with the genus *Orbione*.

Nobili's figure, however, shows the sixth segment definitely continued into the pleural processes. Careful examination clearly reveals the difference in the present

species. The last segment is distinctly marked off from the processes in question, which arise underneath it. The use of the binocular dissecting microscope with powerful illumination makes this very obvious. The processes at the sides of the pleotelson are not pleura but the exopodites of the uropods. They are so sharply marked off that the break can be shown in photographs as indicated in Fig. 1, Plate xiv (see also Text-fig. 1).

This point has been emphasized, for it implies that other species, old and new, should be carefully examined. The possibility of confusion is increased owing to the fact that the exopodites of the pleopods are not unlike their corresponding pleura in appearance (Text-fig. 1). Any resemblance therefore between the exopodites of the uropods and the pleura of the preceding segment is not surprising.

It is interesting to note that Nierstrasz and Brandis make the following remark in their introduction: "Bezuglich der Uropodien mussen wir gestehen dass uns in den Fallen, in welchen sie als Verlangerungen der Seiten des Pleotelsons auftreten und keine Grenzen wahrnehmbar sind, ein criterium fehlt, um sie als Uropodien oder als Seitenplatten zu deuten." In any case the present species is certainly distinct and in view of the facts given above must be made the type of a new genus closely related to *Orbione* and *Parapenacon*.

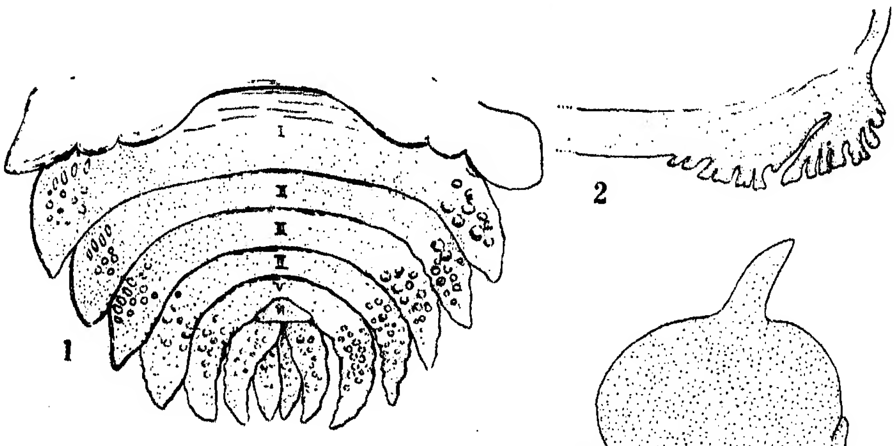
Description of Species.

CRASSIONE ARISTAEI, n. sp.

Female.

Size.—The length of the specimens ranges from 10 mm. to 15 mm. The latter size is the most frequent. The greatest breadth of these individuals is 10 mm. The relation of the cephalon to the peraeon is roughly 5–1.

Cephalon.—As long as broad from the anterior margin of the frontal lamina. The frontal lamina is well developed and projects forward. It is overlapped

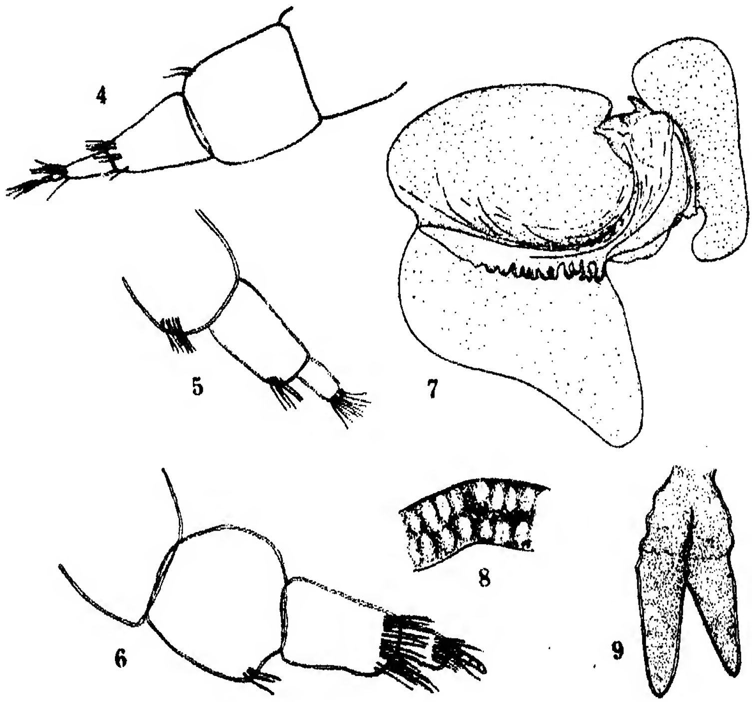


Text-figs. 1-3.—*Crassione aristaei,* n.g. et sp.
1.—Abdomen of female, dorsal view showing biramous uropods of last segment between the pleura of preceding segment. × 15. 2.—Posterior ventral margin of frontal lamina—left half only shown. × 18. 3.—Maxillipede of left side. × 13.

slightly at the sides by the first pleura. Its full length is longer than the breadth of the head. Eyes are absent. Posterior lamina of the head with branched processes on distal margin (Text-fig. 2). Maxillipede (Text-fig. 3) flattened and with flat cone-like endopodite not unlike that of *Orbione* species (*O. halipora* N. & B. for example).

The antennule is three-jointed and not very different from that of the male (Text-fig. 5). The antenna (Text-fig. 4) is composed of four large segments and three, possibly four, very small terminal ones making seven or eight altogether.

Peraeon.—The thoracic segments (see Plate xiv, fig. 1) are all distinctly marked off from one another, although there is a tendency for this to be less so in the median line in connection with the anterior free segments 3, 4 and 5 (the first free thoracic segment is of course really the second thoracic segment). The first



Text-figs. 4-9.—*Crassione aristaei*, n.g. et sp.
4.—Antenna of female. × 100. 5.—Antennule of male. × 150. 6.—Antenna of male. × 170. 7.—First peraeopod with oostegite, view of inner face. × 10. 8.—Ventral surface of an abdominal segment of female. × 19. 9.—Uropod of female. × 15.

four free segments bear very well developed pleura, particularly on the undeformed side. These plates, like those of *Orbione* species, project freely anteriorly and posteriorly. They have a characteristic shape and their free margins are delicate, without any conspicuous crenulation or cuts, although there may be slight undulations. On the undeformed side each pleuron overlaps the one in front and thus extends quite a little distance in front of its own segment. The pleura of the

posterior three segments of the undeformed side of the thorax appear as continuations of the entire margin of the segments; they are somewhat triangular in shape. The sixth overlaps the seventh and there is a steady diminution in size.

On the ventral surface the oostegites (Text-fig. 8) overlap so that the marsupium is completely enclosed.

Abdomen.—The abdomen is about one-fifth the total length of the body and about as broad as long. All the six segments are distinct, the last being quite small. The pleura are pointed and leaf-like tuberculate plates. On the non-deformed side the first pleuron is distinctly smaller than the last thoracic pleuron of this side, and the size somewhat increases so that the fifth is the largest. On the deformed side of the animal the abdominal pleura escape the reduction so obvious in the thoracic region. In fact, the abdominal pleura of this side are slightly better developed than those of the other side and the first abdominal pleuron of the deformed side is actually larger than the last thoracic pleuron.

The ventral surface of the abdomen bears five pairs of biramous pleopods and one pair of biramous uropods. The external ramus of the latter is very like the pleuron of the fifth segment in size and shape. The tips of the exopodites of the pleopods may only just be seen from the dorsal surface—the exopodites of the uropods are of course fully exposed. The pleopods are tuberculate and the ventral surface of the abdominal segments between them also bears little elevations (Text-fig. 8).

Male.—Averages about 4·3 mm. long and 1·7 mm. broad. As in *Orbione*, *Epipenaeon* and *Parapenaeon* the abdomen exhibits a complete fusion of all the segments and there is no trace of pleopods or uropods. The illustration gives the proportion and shape of the head and thoracic segments which increase in breadth slightly to the fourth. The thoracic segments are very distinct, for each lateral margin projects considerably and there are very deep indentations between segments. Eyes are absent. The antennules (Text-fig. 5) are three-jointed, the antennae (Text-fig. 6) 7 or 8-jointed. The proportion of the joints is shown in the figures. It would appear from the literature as if the antennae of allied species had never been examined with a high power. One wonders, therefore, whether the number of antennal joints noted above is characteristic of the present species because it is greater than the number usually found in the allied forms, or whether the smaller terminal joints have been overlooked in those species. As a matter of fact the number of joints is frequently given in diagnosis.

Notes on the Species.—Every prawn examined, with the exception of one, was parasitized. Only one female and its male partner were present, the male lying across the abdomen of the female. Owing to the large size of the female parasite its presence is exactly noted externally, by reason of the large bulge occasioned on the branchiostegite covering it. Sometimes the parasite is on the left side of the prawn, sometimes on the right, but always lying with its head directed towards the host's posterior end. A parasite from the right side of the host has its left side deformed or reduced, whilst one from the left side of the host has its right side reduced. No indication of any external effect of the parasite on the sexual characters of the host was noted, but in this species of prawn the secondary sexual differences are very slight and in any case we had not enough non-parasitized specimens to enable us to recognize minute modifications. It is doubtful whether any occur.

This new species of Bopyrid is distinguished by the following features of the female: (1) Size and relation of length and breadth; (2) the character of the

segments and appendages of the abdomen; (3) the incubatory cavity; (4) the characters of the frontal lamina, the head and thoracic pleura; and (5) possibly by the number of segments in the antennae.

Locality.—The prawn host upon which the species is found was trawled off the coast of New South Wales (off Eden) in 50 fathoms.

The holotype is in the Australian Museum Collection, No. P.9966.

Classification.—It being necessary to erect a new genus, the name *Crassione* is selected. The specific name chosen for the Holotype and type species of the genus is *aristaei*, from the genus of prawns, *Aristeus*, on which it is parasitic.

The systematic position is then as follows:

Class Crustacea.
Div. Peracarida.
Order Isopoda.
Sub-Order Epicaridea.
Tribe Bopyrina.
Genus Crassione.

Bibliography.

A considerable number of articles have been referred to, but since an excellent bibliography has been given by Chopra and by Nierstrasz and Brandis, only the more significant works concerned in this paper need be indicated.

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EXPLANATION OF PLATE XIV.

Fig. 1.—Female *Crassione aristaei*, n.g. et sp., dorsal view. × 6.
Fig. 2.—Male *Crassione aristaei*, n.g. et sp., dorsal view. × 15.

NOTES ON AUSTRALIAN DIPTERA. XXVIII.

By J. R. MALLOCH.

(Communicated by Dr. G. A. Waterhouse.)

[Read 29th July, 1931.]

I present in this short paper some data upon the family Rhagionidae which it is hoped will prove of interest to students of geographic distribution, as well as to those who are more directly and exclusively interested in the family systematically.

Suborder BRACHYCERA.

Family RHAGIONIDAE.

This family has generally been referred to under the name Leptidae. Fabricius described *Rhagio* in "Systema Entomologica" in 1775, but rejected it in 1805 because of its similarity to *Rhagium* (Coleoptera), and used instead for the same concept the generic name *Leptis* (Systema Antliatorum). The change was unnecessary, but was followed by all subsequent writers until comparatively recently and even yet the family name Leptidae is in quite general use, but some of the most recent writers have reverted to *Rhagio* with its concomitant change in the family name to Rhagionidae.

I present below a key to the genera of the family recorded from Australia and Tasmania, in which I introduce some additional characters to those generally met with in similar treatments of the family. This action is taken to bring out the relations of the Australian and extralimital genera more clearly than has previously been done, and in the notes on the genera I have attempted to point out the principal distinctions between those known to me and recorded as Australian. I have done similar work in connection with Asilidae and Stratiomyiidae in previous papers and I note that Hardy has dropped the use of the generic name *Deromyia* in the former family in concurrence with my statement that that genus does not occur in Australia. He has also accepted the character of the complete prosternum in the asilid subfamily Laphrinae as the distinguishing character of that group as pointed out in one of my papers in this series.

Key to the Genera.

1. Five complete posterior cells in the wing, media with four complete branches, the fourth emanating from the medio-cubital cross vein (m-cu) or extremely close to the junction of the latter with the discal cell (m c) 2

   Four complete posterior cells in the wing, media with but three complete branches, the third rudimentary or fused with fourth, the latter always emanating from discal cell (m c) very distinctly beyond the point of entry of the medio-cubital cross vein (m-cu) 5

2. Arista with very distinct segmentation under a moderately high magnification (× 34); distance between apices of subcosta (Sc) and first vein (R_1) on the costa not greater than that between the latter and apex of second vein (R_{2+3}), the latter not curved forward at tip, straight or slightly undulated .. *Atherimorpha* White

Arista without evident segmentation under a moderately high magnification (× 34); distance between apices of subcosta and first vein on the costa much greater than that between the latter and apex of second vein, the latter markedly curved forward at apex and sometimes connecting with apex of second vein at its junction with costa 3

3. Eyes haired; fore tibiae with an apical ventral spur .... *Dasyomma* Macquart

Eyes bare; fore tibiae without an apical ventral spur 4

4. Arista dorsal; hind tibiae with two apical ventral spurs; metapleural hairs confined to the supraspiracular convexity .... *Atherix* Meigen

Arista apical; hind tibiae with but one apical ventral spur; metapleural hairs extending above the upper level of supraspiracular convexity to lateral angle of scutellum, covering the entire extent of disc and denser above than on the convexity .... *Chrysopilus* Macquart

5. Third antennal segment with a slender, tapered, unsegmented apical arista or style which is quite variable in length; third branch of media (M_3) frequently represented by a short spur; hind tibiae without apical spurs .... *Spaniopsis* White

Third antennal segment with a stout, untapered, apical four-segmented process; third branch of media fused with fourth; hind tibiae with two short spurs .... *Austroleptis* Hardy

Genus Atherix Meigen.

This genus is included on the basis of *Atherix pusilla* Macquart which has not been recorded since its original description and may not belong to this genus. For reference of this and other species in this paper see Hardy's paper on the family (*Papers and Proc. Roy. Soc. Tasmania*, 1919, p. 117).

Genus Spaniopsis White.

All the species of this genus are recorded as blood-suckers, and in addition to having this habit in common with Tabanidae they quite closely resemble small tabanids in general habitus, being much more robust than the general run of species in this family, the figures given by Ferguson in his paper on the genus (*Journ. Proc. Roy. Soc. N.S.W.*, xlix, 1915, Pl. 26) reminding one very forcibly of the genus *Haematopota* Meigen.

In structure the genus may at once be distinguished from Tabanidae by the lack of well-defined segmentation of the composite third antennal segment which terminates in a style of variable length, and the large alar and rudimentary thoracic squama. In Tabanidae the slender apical portion of the third antennal segment is distinctly annulated, and the thoracic squama projects distinctly beyond the alar one. This squamal distinction is reliable as a criterion for the separation of the two families where the apical portion of the third antennal segment is distinctly segmented in certain leptid genera.

Spaniopsis clelandi Ferguson.

In this species the following characters are present, but without access to the other species I can not say which hold throughout the genus. Upper two-thirds or more of the frons densely haired; basal segment of antennae and the entire face bare, propleura and posterior portion of mesopleura haired, remainder of pleura and the thoracic sternum bare. In the specimens before me I can detect no segmentation of the slender apical process of the third antennal segment, although Hardy calls it a "thickened jointed appendage."

Four females, Blue Mts., N.S.W., 30.3.1910 (W. W. Froggatt). United States National Museum. There is no reference to the specimens biting on the label, but the letter covering their submission to Coquillett is not available, so I am unaware of the circumstances surrounding the sending.

SPANIOPSIS LONGICORNIS Ferguson.

This species differs from the foregoing one in having the antennae very much longer, the third segment being distinctly longer than the head, with the slender portion about seven times as long as the basal width of the segment. In addition the sternopleura has some hairs on the upper portion which I can not detect in any of my specimens of *clelandi*, and the hairs on the posterior margin of the mesopleura are confined to the small isolated sclerite at the upper posterior angle instead of being scattered along the entire hind margin.

Seven females, Mittagong, N.S.W., 8.5.1901 (W. W. Froggatt). United States National Museum. No data as to whether these specimens were biting is given on labels.

Genus DASYOMMA Macquart.

This genus has been recorded from Tasmania by Hardy (*Pap. Proc. Roy. Soc. Tasm.*, 1919, p. 123). I have examined four South American species of the genus, including the genotype, and present the following notes thereon so that the generic status of the Tasmanian species may be checked by anyone having such available. The hairing of the pleural sclerites is, in my opinion, of considerable importance in limiting the genera in this family and it is to this character that I would direct attention at this time. About the only references in the literature of the family to this character are some of quite indefinite nature by Leonard in his revision of the North American, and by Bezzi in his paper on South African Rhagionidae. Hardy makes no mention of the character in any of his papers on the family.

The South American species of the genus have the third antennal segment much less elongate, or pyriform, than shown in Hardy's Figure 6 of the paper above referred to, and almost identical with his Figure 3 representing the antenna of *Chrysopilus*. The arista is not noticeably segmented, and the face is bare. Propleura, hind portion of mesopleura, and the metapleural convexity, haired, the other portions of the pleura bare. Second wing-vein ending in or very close to apex of first on costa, third vein (R_{4+5}) haired above to its furcation or beyond it; five posterior cells present, all open; anal cell open, or closed just at margin of the wing. Fore tibia with one, mid and hind tibiae each with two apical ventral spurs.

It may be pertinent to note that *Trichopalpus* Philippi is a synonym of *Dasyomma*, and that Hunter in 1901 proposed to substitute *Trichopalpomyia* for the former which was preoccupied by *Trichopalpus* Rondani in Diptera. Also that *Dasyomma obscurus* Philippi has been recorded as a blood-sucker.

Genus ATHERIMORPHA White.

This genus was originally described from Tasmania, and has been recorded from Australia and South Africa. The latter record, by Bezzi, is rather doubtful, but without an examination of his species it is impossible to give a definite decision as to its generic status.

Before me there are four males of a species from Molong, N.S.W. (Froggatt) that differ from the genotype in having the eyes closely contiguous on the front and possibly they belong to *occidens* Hardy, which was very briefly described as a subspecies of *vernalis* White in the paper already referred to (Hardy, *l.c.* p. 126). Apart from noting that all four specimens are uniform in colour and markings as well as in structure, and that they impress me as likely to prove specifically

distinct from *vernalis*, I do not plan to go, because of lack of other material for comparison, but I have also before me several specimens of a Chilean species which agrees very closely with the Australian one and present some notes on the similarities and distinctions below. The South American species belonging to this group are already described, but they have been placed in the genus *Leptis* (= *Rhagio*).

Both groups are distinguished from *Rhagio* by the segmented arista, five segments being generally evident, the entirely bare face, the longer second wing-vein which enters the costa as far beyond the tip of the first vein as the tip of the latter is from the tip of the subcosta, and the continuation as a linear series of the long bristly hairs on the metapleural convexity up to almost the anterior lateral edge of the scutellum. In *Rhagio* these hairs are confined to the convexity, while in *Chrysopilus* they cover almost the entire metapleura above the level of the bases of the halteres. In the above features the two groups agree, as well as in having the mesopleura and pteropleura bare, and the sternopleura haired below only, but the Australian examples have some setulose hairs on the posterior portion of the postalar declivity just in front of the lateral angle of the scutellum, which are entirely lacking in the South American forms.

The preponderance of similarities in characters over the dissimilarities would suggest the advisability of placing the two groups in one genus, but a division into two subgenera, and for the South American segregate I propose the subgenus *Philippoleptis*, with the type *Leptis praefica* Philippi.

Genus Chrysopilus Macquart.

I have not seen any Australian representative of this genus but have seen several from the East Indies, including also one from Aru Island. Bezzi has recorded *coeruleothorax* Linder from the Fiji Islands.

Hardy has placed the two species described by White as synonyms of *aequalis* Walker, but I rather fear that this may be erroneous, as the genus is one in which the colour characters have to be depended upon largely for specific distinctions, and in other faunal regions than Australia these are quite stable and dependable for that purpose.

THE GASTEROMYCETES OF AUSTRALASIA. XII.

THE GENUS SCLERODERMA.

By G. H. Cunningham,
Mycologist, Plant Research Station, Palmerston North, N.Z.

(Plates xv–xvi; six Text-figures.)

[Read 29th July, 1931.]

The genus *Scleroderma* is placed in the family Sclerodermaceae of the Gasteromycetes and is characterized by the simple peridium, usual irregular method of dehiscence, pulverulent gleba and absence of a definite capillitium. The family is limited to the genera *Scleroderma* and *Pisolithus*, though Fischer (1900, p. 334) included *Melanogaster* and *Corditubera* (members of the Hymenogastraceae), *Pompholyx* and *Sclerangium* (synonyms of *Scleroderma*).

Scleroderma is separated from *Pisolithus* by the pulverulent gleba, for in the latter genus the tramal plates become carbonous and persistent. The morphology of the genus is simple. The peridium is composed of hyphae intricately interwoven to form a firm membrane, which in mature specimens is not or seldom clearly differentiated from the periphery of the gleba. It is usually borne on a short rooting base which is firmly attached to the substratum by numerous well developed, fibrous mycelial strands or rhizoids. Occasionally these unite to form definite cords, which sometimes become aggregated and produce a columnar rooting base often many centimetres long. In one species (*S. radicans*) the hyphae which normally form the rhizoids become intricately interwoven to form a columnar, stem-like tissue which penetrates for several centimetres into the sandy soil in which this plant grows (Pl. xvi, fig. 7).

The peridium encloses the gleba. This is at maturity pulverulent and composed of very numerous spores mixed with a few mycelial threads, which are the remnants of the tramal plates. These are usually termed capillitium threads, but this term is scarcely applicable since these structures are not comparable with the capillitium of the Lycoperdaceae. The spores are of two distinct types, reticulate and verrucose, and serve as excellent characters upon which to group the species.

Development.

The development of members of this genus is comparatively simple. The plants arise as terminal or lateral inflations on the ends of the rhizoids. Sections of these primordia show them to consist of interwoven hyphae without differentiation or arrangement. When plants are about 5 mm. in diameter, glebal development commences. Deeply staining areas arise scattered through the tissue, being more distinct and numerous centrally, scattered and poorly defined peripherally, the greater part of the plant being as yet undifferentiated. These deeply staining areas become aggregated into dense hyphal knots, closely and intricately interwoven. At the same time the surrounding hyphae of the fructification become more

densely compacted and peripherally become arranged with their long axes predominantly radial. Further development is for a time confined to the knots of hyphae which, in addition to increasing peripherally in numbers, increase in size and shortly become oriented so that most surround a lenticular zone. Those hyphae facing towards the centre of this zone become torn apart, their free apices assume a clavate appearance, and become modified as basidia. They enlarge somewhat, and bear sessilely a variable number of spores. At first but one or two spores are produced upon each, but as development continues this number increases, so that basidia in older plants may bear from four to five spores; but the number and position are seldom constant. Opinions differ as to what happens in this plexus of hyphae and basidia subsequently. Beck (1889) claimed that in *Phlyctospora fuscum* Cda. (which Fischer, 1900, p. 336, placed under *Scleroderma*) when the spores were less than half size they became surrounded by a sheath of hyphal cells which served as nutritive or "nurse" cells. A similar condition was reported by Rabinowitsch (1894) in *Scleroderma Bovista*. Coker and Couch (1928, p. 168) found that with *S. lycoperdoides* Schw. the fertile tissue, including the basidia, was broken down into a translucent, almost structureless mass surrounding and embedding the spores, which at this period were hyaline, smooth and only about half size. They concluded that as the basidia disappeared before the spores were more than half developed, this matrix served as a nutritive substance. I have found in *S. flavidum* that the spores, shortly before they are half grown, are surrounded by a number of loosely attached small and hyaline cells, but that these soon gelatinize and embed the spores in a matrix similar to that recorded by Coker and Couch; and in *S. Bovista* a condition similar to that described by Beck and Rabinowitsch.

Additional hyphal knots continue to develop between others in the tramal tissue, and this process continues until finally the whole of the central tissue of the gleba has become converted into spores (and mucilaginous investment), save the peripheral region and (according to the species) scattered rudiments of the undifferentiated gleba which persists as the so-called capillitium. There is no sharp differentiation between the periphery of the gleba and peridium, the zone being continuously interrupted by partial plates of undifferentiated tissue; consequently it often happens that when dehiscence occurs part of the peridium is torn away and left as a fine membrane covering the spore mass. (This additional tissue has been responsible for the erection of the genera *Stella* and, in part, *Sclerangium*). Thus both tramal plates and peridium are but undifferentiated potential sporogenous tissue. In many plants glebal formation continues until the apical portion of the peridium is almost completely converted, when there remains but a shell which ruptures readily.

The genus has proved a difficult one for the systematist, there being little agreement as to the specific limits of the few known species. This confusion has arisen through attempts being made to base species upon such variable characters as the surface of the peridium, colour of the peridium and gleba, and method of dehiscence. Within limits, these characters are useful, but too variable to be used alone in specific diagnosis. For example in the common species of Australia and New Zealand, *S. flavidum*, the peridium may be almost smooth, finely warted, areolate or, in extreme forms, covered with coarse scales. The colour may range from bright citron-yellow to vinaceous brown. The plant may rupture apically in an irregular manner, or it may break into lobes which become strongly recurved and in old specimens stellate, then resembling certain forms of *S. Geaster*. The

gleba may vary from ferruginous to umber-brown, depending (partly) on age at the time of collection, and the locality in which the plant is growing, and may possess persistent tramal plates, or these may be wanting. This variation is not confined to this species alone, but is exhibited by numerous others; for *S. Bovista* may externally exactly resemble *S. cepa*; similarly *S. flavidum* may resemble *S. aurantium*, and both may resemble *S. Bovista*. After examining a large series of specimens I believe that the spores form one of the most reliable guides, as, if their size and markings are considered, it is often easy to place an otherwise difficult specimen. The spores are either definitely reticulate or else covered with acute spines or blunt verrucae. These characters are not readily seen unless the specimens are mounted in a suitable clearing agent. I use a solution of lactic acid in water, for if spores are mounted in this and heated to boiling point their markings are rendered free from obscuring matter, and may be examined critically. As older workers seldom recognized spore characters, it is often difficult to decide the species with which they were dealing. Many of the species considered valid today were erected by Persoon or Fries, and for an interpretation of these in the light of spore characters it is necessary to refer to Hollos (1904) who was the first clearly to describe and illustrate these structures. His work has therefore come to be regarded as the authoritative one for the common European species. Coker and Couch (1928) have likewise used the spores as one of the critical diagnostic features, with the result that the North American species considered in their publication can be recognized readily. Lloyd (1905) worked over the Australian and New Zealand species, and his work has come to be regarded locally as the standard for this region. Unfortunately he appeared to have had but a scant knowledge of the genus, and ignored the spores in his papers, consequently his diagnoses are of little value. This is exemplified by the material named by him in the collections I have worked over, for collections of *S. flavidum* have been referred to no less than six species, of which three are not known with certainty to occur in this region!

SCLERODERMA Persoon.

Ex Fries, *Syst. Myc.*, iii, 1829, p. 44; Pers., *Syn. Meth. Fung.*, 1801, p. 150, *pro parte*.—*Sclerangium* Lev., *Ann. Sci. Nat.*, ser. 3, ix, 1848, p. 132.—*Stella* Mass., *Jour. Myc.*, v, 1890, p. 185.

Plants solitary or in groups, subglobose, pyriform or subturbinate. Peridium firm, consisting of a single layer, externally frequently broken into areolae, verrucae or scales; contracted basally into a short rooting base which is firmly attached to the substratum by (usually) an abundant development of mycelial strands. Gleba formed of tramal plates enclosing cavities in which are produced the spores, becoming pulverulent at maturity. Spores globose, coloured, continuous, externally reticulate or verrucose.

Type Species.—*Scleroderma aurantium* Pers.

Distribution.—World-wide.

The number of species which have been recorded is large, the numerous volumes of Saccardo's *Sylloge fungorum* containing upwards of 60 species; but it is improbable that there are more than about one-sixth this number, the others being synonyms of these or of *Mycenastrum*, with which genus *Scleroderma* was regularly confused by the compilers.

In Australia and New Zealand the genus is represented by the following five species, of which two are confined to Australia. It appears strange that the

common European *S. Geaster*, *S. aurantium* and *S. cepa* have not been found in this region; but of the 95 collections examined, none can be referred to these three well-known species. Equally strange is the absence of *S. Bovista* from Australia, for this appears to be not uncommon in New Zealand.

Key to the Species.

Spores strongly reticulate .... 1. *S. Bovista*.
Spores echinulate or verrucose.
  Spores 6-10 μ diameter, commonly 6-8 μ; finely and densely verruculose .... 2. *S. australe*.
  Spores 10-12 μ diameter, sharply echinulate; peridium covered with fine, darker coloured, deciduous warts .... 3. *S. verrucosum*.
  Spores usually 11-14 μ diameter, or larger, coarsely echinulate or verrucose.
    Peridium thin, leathery and attached by numerous mycelial strands .... 4. *S. flavidum*.
    Peridium thick, hard and woody, usually attached by a firm mycelial tap-root .... 5. *S. radicans*.

1. Scleroderma Bovista Fries. Plate xv, fig. 1; Text-fig. 1.

Syst. Myc., iii, 1829, p. 48.—*S. texense* Berk., Hook. *Lond. Journ. Bot.*, iv, 1845, p. 308.

Plants solitary or gregarious, to 4 cm. diameter, compressed globose, firm, somewhat plicate below, with a short rooting base or almost sessile, and attached firmly to the substratum by a plentiful development of rhizoids. Peridium when dry tough, firm, dehiscing by irregular rupture of the apical portion, rarely by a definite mouth, externally furfuraceous, or less frequently areolate apically, bright sulphur-yellow or more often bay-brown or pallid-umber, often somewhat vinaceous; in section thin, 0·5 mm. or less, yellowish or vinaceous. Gleba at first violaceous, becoming umber-brown; tramal plates often persistent, yellow, hyphae with distinct clamp connections. Spores strongly reticulate, globose, 11–16 μ (commonly 11–13 μ), deep-umber tinged with chocolate, reticulations to 3 μ tall.

Habitat.—Growing amongst grass on sandy or cultivated soil.

Type Locality.—Germany.

Distribution.—Europe; North America; New Zealand.

New Zealand: Auckland, Buried Village, Wairoa, 2/27, J. B. Cleland, G.H.C.; Whakarewarewa State Forest Nursery, 5/28, G.H.C.; Taranaki, Botanical Gardens, New Plymouth, 2/27, G.H.C.; Wellington, Wanganui, 4/25, D. W. McKenzie; Palmerston North, 5/30, 2/31, G.H.C.; Weraroa, 3/25, J. C. Neill.

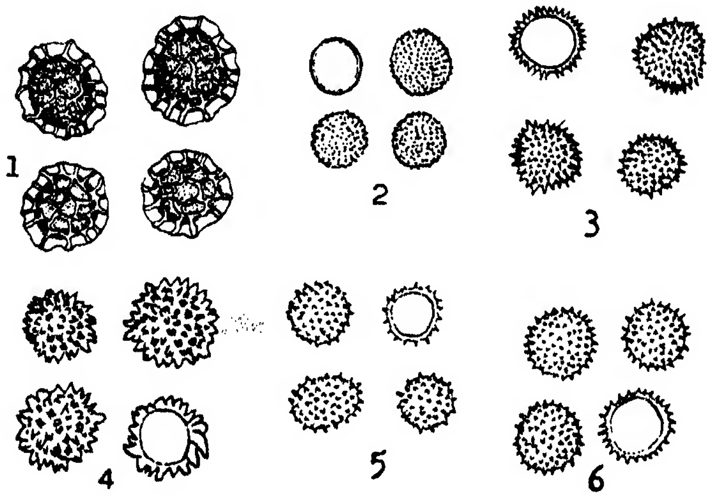
The characters of this species are the strongly reticulated spores, thin but firm, usually externally smooth peridium, and subpersistent yellow tramal plates, the hyphae of which possess abundant clamp connections.

Owing to the confusion which exists in literature, few workers are agreed as to the characters of this species. I am following Hollos (1904, p. 132), Rea (1922, p. 49) and Coker and Couch (1928, p. 163) in considering it to be the plant described above.

As the plant normally grows it is firm and somewhat globose, dark in colour and with a well-developed rooting base; but collections from the Rotorua district (New Zealand) are quite yellow, and more lax. The spores are identical in both, however, so that it is not practicable to maintain these yellow plants as distinct, especially as intermediate forms occur.

It appears strange that the species has not been represented in Australia in the abundant collections in the possession of Dr. Cleland. True, it has been recorded by Cooke (1892, p. 240) from Victoria, New South Wales and Queensland;

but as both he and Berkeley confused the plant with *S. flavidum* (repeatedly identifying this as *S. Bovista*, as the collections at Kew show), it is evident no reliance can be placed upon his records. Lloyd (1905, p. 14) stated that at Kew there were several collections of a plant he called *S. texense*, and considered this was a form of *S. Bovista*. But as his diagnosis was based on the subpersistent tramal plates, a character equally present in *S. flavidum*, it becomes evident that his records, too, are inaccurate.



Text-figs. 1-6.

1.—*Scleroderma Bovista*. Spores showing reticulations.
2.—*Scleroderma australe*. Spores showing fine verrucae.
3.—*Scleroderma flavidum*. Spores from typical form.
4.—*Scleroderma flavidum* forma *macrosporum*. Spores from a plant in which they are larger and more coarsely warted than in the typical form.
5.—*Scleroderma verrucosum*. Spores showing the somewhat sparse spines.
6.—*Scleroderma radicans*. Spores showing spines.
(All spores are × 1000; they have been drawn with the aid of a projection apparatus, from lactic acid mounts).

S. Bovista is often found associated with healthy roots of *Pinus radiata* in the forest nursery at Whakarewarewa, and has been found similarly with strawberries at Palmerston North. It is probable that the species form a mycorrhiza with the former host, since Peyronel (1922) found that *S. "vulgare"* formed mycorrhiza with roots of *Larix decidua* and *Quercus robur* in Italy.

2. Scleroderma australe Massee. Plate xv, fig. 2; Text-fig. 2.

Grevillea, xviii, 1889, p. 26.

Plants solitary or crowded, to 4 cm. diameter, commonly much less, subglobose, pyriform or subturbinate, firm, basally plicate and attached by a short rooting base, or not infrequently sessile and attached by several scattered basal mycelial cords. Peridium when dry tough, tardily rupturing by irregular crevices, lobes in old and weathered plants becoming somewhat recurved and stellate;

externally bright lemon-yellow, often bay-brown, areolate apically, and sometimes with smooth flattened scales of a deeper colour, or almost smooth; in section thin, 0·5 mm., yellowish. Gleba at first violaceous, becoming umber-brown; tramal plates seen usually only in young plants, yellowish. Spores globose, 6–10 μ (commonly 6–8·5 μ), finely verrucose; spines acute at apices, broad at bases and only 0·5 μ long.

Habitat.—Growing solitary or in small groups in sandy soil.

Type Locality.—Endeavour River, Queensland.

Distribution.—Australia.

Queensland: Endeavour River (Massee, *l.c.*).—New South Wales: Sydney* (Lloyd, No. 119, as *S. flavidum*); Neutral Bay, 6/12*, 3/19*; The Oaks, 6/14*; Terrigal, 6/14*; Mt. Irvine, 6/15* (Lloyd, No. 118, as *S. cepa*); Milson Island, 6/16*; Kendall, 12/17*, 3/18*; Bradley's Head, Sydney, 4/19*; Sydney, no date* (two collections); no locality* (three collections).—Victoria: Grantville, J. T. Paul (Herb. Vic. Dept. Agr., Lloyd, as *S. flavidum*).—South Australia: Mt. Lofty, 7/14*.

SCLERODERMA AUSTRALE, var. IMBRICATUM, n. var.

Peridium to 5 cm. diameter, subturbinate, firm and rigid; attached by a small rooting base, almost sessile; externally covered with coarse imbricate scales, ferruginous in colour; in section to 2·5 mm. thick, bay-brown. Gleba umber-brown. Spores as above.

Habitat.—At the base of a tree trunk in burnt ground.

Distribution.—Australia.

New South Wales: Narrabeen, 4/15* (Lloyd identified this as *S. Geaster* and it was so recorded by Cleland and Cheel, *Journ. Proc. Roy. Soc. N.S.W.*, l, 1916, p. 114).

This usually small species appears to be relatively common in New South Wales, but apparently rare in the other States. It is characterized by the small spores, with their fine verrucae, yellowish colour, usually strongly areolate surface of the peridium, and frequent attachment to the substratum by several stout cord-like rhizoids. Superficially, plants resemble *S. flavidum* in the yellowish colour, areolate upper portion of the peridium, and stellate dehiscence as shown by old and weathered plants; but differ in the much smaller, finely verrucose spores and the frequent darker colour of the surface areolae.

The variety *imbricatum* was identified by Lloyd as *S. Geaster*. It certainly has the thick peridium and imbricate scales of forms of this species; but as the spores are the same as *S. australe* it must be considered as distinct from *S. Geaster*, in which the spores are reticulated (Rea, 1922, p. 50) or imperfectly so (Coker and Couch, 1928, p. 162). The size of the spores of *S. Geaster* is given by Rea as being 12–15 μ, whereas Coker and Couch state they are but 5–10 μ. Apart from this aberrant specimen (placed under the variety *imbricatum*) *S. australe* differs from *S. Geaster* in being much smaller, and in its different dehiscence and much thinner wall of the peridium.

The plant agrees well with the description of *S. australe* as published by Massee, so I am using his name; but comparison with the type is no longer possible as, according to Lloyd (1905, p. 14), he was unable to find this at Kew.

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* An asterisk denotes that the collection in question is in the herbarium of Dr. J. B. Cleland, Adelaide; and where no collector is given, the collection has been made by Dr. Cleland himself.

3. Scleroderma verrucosum (Vaillant) Persoon. Plate xv, fig. 3; Text-fig. 5.

Syn. Meth. Fung., 1801, p. 154.—*S. areolatum* Ehrenb., *Sylv. myc. Berol.*, 1818, p. 27.—*S. pandanaceum* F.v.M. ex Berk., *Journ. Linn. Soc.*, xiii, 1872, p. 171.—*S. Bresadolae* Schulz., *Hedw.*, xxiii, 1884, p. 163.—*S. Torrendii* Bres., *Atti I.R. Acc. Sci.*, ser. 3, viii, 1902, p. 132.

Plants solitary, small, to 4 cm. diameter, fragile, depressed globose, not plicate below, contracting into a short stem-like rooting base which is attached to the substratum by mycelial strands. Peridium when dry fragile, lax, dehiscing by a small torn mouth, which later becomes torn and distorted, externally ochraceous or umber, sometimes with a purplish cast, typically covered with small, deciduous, raised, umber warts, more numerous and larger apically, absent near the base, which is smooth and lighter in colour; in section 0·2–0·5 mm. thick, ochraceous. Gleba at first with an olivaceous tinge, becoming umber; tramal plates whitish, becoming dingy-grey, scanty. Spores globose, sometimes subglobose, 9–12 μ in diameter, pallid ferruginous-brown, closely and coarsely echinulate; spines with acuminate apices, narrow bases, and to 1·5 μ long.

Habitat.—Growing solitary on the ground in sandy soil.

Type Locality.—Europe.

Distribution.—Europe; Africa; Asia Minor; Australia.

South Australia: Mt. Lofty, 4/24*.—New South Wales: Hawkesbury River, 6/12, J. B. Cleland (Herb. Vic. Dept. Agr.); Neutral Bay, 6/12*, 12/15*, 5/19*; Mosman, 5/14*, 5/19* (Lloyd, No. 520, as *S. verrucosum*); Bulli Pass, 4/14* (Lloyd, No. 121 as *S. verrucosum*); no locality* (two collections).

This species may be recognized by its brittle, thin peridium, externally covered with darker warts, the manner of dehiscence, small but distinct rooting base, and the characteristic echinulate spores. The plant is usually smaller in Australia than in Europe, and the spores are also slightly smaller. But as I have small specimens from Europe (ex Bresadola herbarium) which cannot be separated from the Australian plant, it is evident that our plant is but a form of the European one. The species is in North America replaced by the very similar *S. lycoperdoides* Schw., which differs from the Australian plant by the larger spores, different method of dehiscence and subpersistent hyphae of the tramal plates.

4. Scleroderma flavidum Ellis and Everhart. Plate xvi, figs. 4, 5; Text-fig. 3.

Journ. Myc., i, 1875, p. 88.—*S. caespitosum* Lloyd, *Myc. Notes*, 1922, p. 1159.—*S. flavidum* var. *fenestratum* Clel. et Cheel, *Trans. Roy. Soc. South Aus.*, xlvii, 1923, p. 75.

Plants solitary or gregarious, sometimes caespitose, growing half buried until maturity, to 5 cm. diameter, firm, pyriform, or subturbinate, often lobed, usually plicate below, contracting into a mass of mycelial fibres, which occasionally form a conspicuous stem-like base. Peridium when dry tough, leathery and seldom brittle, to 1 mm. thick, dehiscing by irregular rupture into several lobes, which in old weathered plants frequently become recurved and stellate; pallid-straw colour, bright lemon-yellow, or tinged vinaceous, often drying dingy-brown, finely areolate above, sometimes almost smooth. Gleba at first olivaceous, becoming dingy-ferruginous or umber-brown; tramal plates often subpersistent, yellow. Spores globose, 10–14 μ (commonly 10–13 μ), coarsely and densely echinulate; spines acuminately pointed, somewhat narrow at their bases, to 1·5 μ long.

Habitat.—Growing on sandy soil, or partially buried in clay or rock cuttings.

Type Locality.—New Jersey, North America.

Distribution.—North America; Africa; Australia; New Zealand.

South Australia: Kuitpo, 5/21* (two collections); Mt. Lofty, 7/14*; near Adelaide, 1930*; Overland Corner, 12/13*; Eagle-on-Hill, 1920* (Lloyd, No. 692, as *S. flavidum*); same locality, 6/21*; no locality* (three collections).—New South Wales: Milson Island, 6/12* (Lloyd, No. 120, as *S. flavidum*); Sydney, 4/19*; east of Broken Hill, Dr. Pulleine*; Narrabri, 10/18* (Lloyd, No. 532, as *S. aurantium*). —Western Australia: Donnybrook, 8/26*; Dwarda, 8/26, W. M. Carne; Ludlow, 8/20, J. Clark (these two collections in herb. Dept. Agr. W. Aus.).—New Zealand: Wellington, 5/22, J. B. Cleland*.

forma MACROSPORUM. Text-fig. 4.

Spores larger, to 19 μ (commonly 14-16 μ) and with more coarse spines, which sometimes appear as fused warts. Otherwise identical with the typical form.

Distribution.—South Australia: Adelaide, Mr. Zietz*; Mt. Lofty, 5/10*, 7/20*, 3/24*, 6/25*; Mt. Remarkable, 8/27*; no locality* (eight collections).—New South Wales: Sydney*; Bibbenluke, 3/13*.—Victoria: Dimboola, 7/90, 6/91 (two collections, the former identified by Lloyd as *S. Geaster*, the latter as *S. Bovista*; both in herb. Vic. Dept. Agr.); Ararat, 5/18, E. J. Semmens*; Dandenong, 7/17, C. C. Brittlebank*.—Western Australia: Pemberton, 8/26* (two collections); Mundaring, 7/25, W. M. Carne.—Tasmania: No locality, L. Rodway.—New Zealand: Auckland, Waitakere, 9/21, D. Miller; Rotorua, 7/23, G.H.C.; Wellington, Botanic Gardens, 5/22, 10/22, 1/23, G.H.C. (seven collections); Kelburn, 10/23, G.H.C.; Nelson, 2/20, G.H.C. (Lloyd, as *S. cepa*); Otago, Deborah Bay, 9/26, Miss H. K. Dalrymple; Dunedin, 5/22, 9/22, 7/23, Miss Dalrymple (all in writer's herbarium).

The characters of the species (typical form) are the firm, areolate, relatively thick peridium, method of dehiscence and frequent stellate appearance of old specimens, subpersistent tramal plates, and definitely echinulate spores. The form *macrosporum* appears to differ only in that the spores are larger and more coarsely warted; but as numerous intermediate forms occur it is not possible to separate it other than as a form.

The species has doubtless been the basis of most of the records by Cooke (1892, p. 240) of the occurrence in Australia of *S. aurantium* (many plants being yellow in colour), *S. Geaster* (as in old plants the peridium becomes lobed and the lobes recurved and stellate), and *S. vulgare* (which consists of both *S. aurantium* and *S. cepa*); for it is decidedly variable in size, form, colour and surface markings and the degree of development of the mycelial rooting base. From *S. aurantium* and *S. Geaster* it is separated by the echinulate spores (reticulate in these two species), and from *S. cepa* (its nearest relative apparently) by the usually larger spores, and especially in the thicker, differently coloured, areolate peridium. As I have shown above, Lloyd had difficulty with the species, for he named different collections from Australia *S. aurantium*, *S. flavidum*, *S. Geaster*, *S. Bovista*, (and from New Zealand) *S. cepa* and *S. caespitosum* (this last being based on a form not uncommon in New Zealand where it grows in rock cuttings, the plants being compacted together owing to the limited space available in the rock crevices in which it develops). But this is scarcely to be wondered at, since he attempted diagnosis upon the nature of the surface of the peridium and manner of dehiscence, characters which are worthless specifically in this difficult genus.

Judging from the numerous collections I have examined, this would appear to be the most frequent and variable species in Australia. It is not practicable to

maintain the variety *fenestratum*, for it appears in both large and normal spored forms and in addition in other species (as *S. radicans*). Brittlebank stated (*vide* Cleland and Cheel, 1923, p. 76) that the species was found at Dandenong to parasitize the roots of roses.

5. SCLERODERMA RADICANS Lloyd. Plate xvi, figs. 6, 7; Text-fig. 6.

Mycological Notes, 1906, p. 246.

Plants solitary, to 5 cm. diameter, subglobose, obovate or subpyriform, firm, plicate below, with usually a strong compact mycelial rooting base which is not broken into fibres but forms a solidly interwoven tissue of hyphae and sand. Peridium when dry hard, firm and woody, dehiscing by irregular breaking away of the upper portion, not lobed, long indehiscent, externally furfuraceous or minutely and irregularly areolate, pallid-white, becoming ochraceous; in section to 5 mm. thick, commonly 1·5–2 mm., but thicker below and pallid-ochraceous. Gleba at first ferruginous, becoming umber; tramal plates white, becoming greyish, scanty and practically disappearing in old plants. Spores globose, chestnut-brown, 12–14 μ (up to 16 μ), densely, closely verrucose-echinulate; spines acuminate at their apices, moderately broad at their bases, and (including the wall of the spore) to 2 μ long.

Habitat.—Growing under scrub, often buried in sand.

Type Locality.—Bank of the Wimmera River, Victoria.

Distribution.—Australia.

Victoria: Wimmera River, F. M. Reader (Lloyd, *l.c.*).—New South Wales: Baradine, 10/18*; Wangan, 10/18* (two collections, Lloyd, Nos. 553, 554, as *S. flavidum*); Narrabri, 10/18*.—South Australia: Murray River*; probably near Overland Corner*.—Western Australia: Bindoon, 9/25, W. M. Carne.

The species is characterized by the thick, hard and woody peridium, which basally attains a thickness of 5 mm., pallid colour, greyish, scantily developed tramal plates, and peculiar rooting base. This last consists of a dense tissue of interwoven hyphae in part mixed with sand, and is quite distinct from the fibrous rooting system of other species recorded herein. It was upon this character that Lloyd erected the species; but as I have shown, it differs in many other particulars from *S. cepa*, with which Lloyd stated it was closely related (possibly because of the usually smooth peridium). The spores are close to those of *S. flavidum*, so that plants lacking the peculiar base might be placed under that species; but the hard and woody, thick, light-coloured peridium and scanty tramal tissue serve to distinguish it.

Doubtful and Excluded Species.

a. Scleroderma aurantium Pers.—Recorded by Lloyd (*Letter 66*, 1917, p. 15) from Australia. This is a misdetermination of *S. flavidum* as has been shown under this species.

b. Scleroderma aureum Mass., *Grev.*, xviii, 1889, p. 26.—Recorded by Massee from New Guinea. It was said to possess smooth spores 5 μ in diameter, which seems improbable. The description reads as if the species were based on an immature specimen of *S. flavidum*, but the matter cannot be solved apparently, since Lloyd (1905, p. 14) stated that he was unable to find the type at Kew.

c. Scleroderma cepa Pers.—Lloyd frequently recorded this species from Australia (*Letter 17*, 1907, p. 3; *Letter 23*, 1908, p. 3; *Letter 30*, 1911, p. 6; *Letter 53*, 1914, p. 14; *Letter 62*, 1916, p. 2; *Letter 63*, 1916, p. 5–8; *Letter 66*, 1917, p. 3;

Letter 67, 1918, p. 10; *Myc. Notes*, 1921, p. 1074; *Myc. Notes*, 1922, p. 1120), from Tasmania (*Myc. Notes*, 1921, p. 1089) and New Zealand (*Letter* 8, 1905, p. 2; *Letter* 67, 1918, p. 2; and *Myc. Notes*, 1922, p. 1160). But from his notes and the specimens I have examined I believe his records to be based on young specimens of *S. flavidum* and mature plants of *S. Bovista*. (See his determinations under these two species). A stipitate form he figured (*Myc. Notes*, 1918, p. 759) as *S. columnare*. This appears to be based on a specimen of *S. Bovista* with a somewhat abnormal development of the stem-like base.

d. S. Geaster Fr.—Lloyd (*Myc. Notes*, 1906, p. 246; *Letter 61*, 1916, p. 3) recorded this species from Australia and (*Myc. Notes*, 1923, p. 1186) from New Zealand. I have examined specimens he has so determined and find two are typically *S. flavidum*, the third being *S. australe* var. *imbricatum*. Cooke (1892, p. 240) recorded the species from every State in Australia and also from Tasmania; but his records appear to be based on *S. flavidum*, as numerous collections at Kew labelled *S. Geaster* are of this species.

e. S. olivaceum (Cke. et Mass.) de Toni.—This is a synonym of *Mycenastrum corium* (Guers.) Desv.

f. S. pandanaceum F.v.Muell. ex Berk., *Journ. Linn. Soc.*, xiii, 1872, p. 171.—This I believe to be a synonym of *S. verrucosum*, although the description is so poor as to make specific diagnosis impossible. Lloyd (1905, p. 14) was unable to find the type at Kew.

g. S. phaeotrichum (Berk.) de Toni.—This is a synonym of *Mycenastrum corium*.

h. Scleroderma (*Areolaria*) *strobolina* Kalch.—This is a synonym of *Phellorina strobilina* Kalchbr. et Cke.

i. S. umbrina Cke. et Mass.—This is a synonym of *Pisolithus tinctorius* (Pers.) Coker et Couch.

j. S. vulgare (Hornem.) Fr.—This has been recorded from most of the States by Cooke (1892, p. 240) and from New South Wales by Lloyd (*Letter 63*, 1916, p. 3). It is now known to consist of the two species *S. aurantium* and *S. cepa*, neither of which, as I have shown, has with certainty been collected in this biologic region.

Acknowledgements.

Once again I must express my indebtedness to Dr. J. B. Cleland for the loan of the large number of collections in his possession. I must also thank Mr. L. Rodway, Tasmania, Mr. C. C. Brittlebank, late of the Department of Agriculture, Victoria, and Mr. W. M. Carne, of the Department of Agriculture, Western Australia, for the loan or donations of specimens in their collections. Thanks are also due to Mr. H. Drake, of this Station, for the excellent photographs reproduced herein.

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EXPLANATION OF PLATES XV-XVI.

Plate xv.

Fig. 1.—*Scleroderma Bovista.* × $\frac{2}{3}$. Note the almost sessile, smooth peridium and the strong development of mycelial fibres.

Fig. 2.—*Scleroderma australe.* × $\frac{2}{3}$. This photograph well shows the strongly areolate peridium, method of dehiscence, and cord-like rooting strands.

Fig. 3.—*Scleroderma verrucosum.* × $\frac{2}{3}$. The darker coloured warts and areolate exterior of the peridium are well shown in this photograph. A plant has been sectioned to show the variations in the surface markings on different sides of the same peridium.

Plate xvi.

Fig. 4.—*Scleroderma flavidum*, typical form. × $\frac{1}{3}$. Note variations in the surfaces of the plants on right and in the centre. A stellate weathered plant is shown on the left.

Fig. 5.—*Scleroderma flavidum.* × $\frac{1}{2}$. Plant showing the finely areolate peridium and strong development of the mycelial rhizoids.

Fig. 6.—*Scleroderma radicans.* × $\frac{1}{3}$. Note the almost smooth exterior. The strongly developed mycelial tap root has been broken away from this specimen.

Fig. 7.—*Scleroderma radicans.* × $\frac{2}{3}$. Plant at top left exactly resembles the plant from which Lloyd described the species; on the right is shown the peculiar tap root; and on the lower left is shown a section exhibiting the thick woody peridium, and gleba almost free from rudiments of tramal tissue.

(All photographs by H. Drake.)

THE GASTEROMYCETES OF AUSTRALASIA. XIII.

THE GENUS PISOLITHUS.

By G. H. Cunningham,

Mycologist, Plant Research Station, Palmerston North, N.Z.

(Plate xvii.)

[Read 26th August, 1931.]

As has been shown in the previous paper, the family Sclerodermaceae is limited to the genera *Scleroderma* and *Pisolithus*. The latter differs from the former in that the tramal plates, instead of breaking up and disappearing in mature plants, remain to form a honeycomb-like tissue. This is due to the persistence of the tramal plates, the hyphae of which are infiltrated and gelatinized to form a firm, carbonous, brittle tissue. The spore mass at maturity completely fills these cavities; and in developing plants is enclosed within a delicate hyphal layer, free from the carbonous tramal plates. Because of this, these spore masses have been termed peridiola, a term which has persisted since the days of Fries; but as they are not comparable with the peridiola of the Nidulariales, the term is a misnomer and should be discarded. In typical plants the peridium is supported upon a firm rooting base, and as this structure is also carbonous in mature plants, it frequently persists for long after the more fragile peridium has been dispersed. The genus is at home in warm sandy regions, and, although common in Australia, is confined to the thermal regions of the North Island of New Zealand.

Pisolithus Albertini and Schweinitz.

Consp. fung. Lusatiac sup. Nisk. cresent., 1805, p. 82.—*Scleroderma* Pers., *Syn. Meth. Fung.*, 1801, p. 151, *pro parte*.—*Polysaccum* DC. et Desp., *Rapp. voy. bot. l'Ouest Fr.*, i, 1807, p. 8.—*Pisocarpium* Link, *Mag. Ges. nat. Freunde Berlin*, iii, 1809, p. 33.

Plant consisting of a peridium supported on a stem-like rooting base. Peridium of a single thin membranous layer, flaking away irregularly from the apex. Gleba divided into polygonal cells by the persistent tramal plates; cells filled with the spore mass, a true capillitium wanting. Spores coloured, globose, verrucose.

Habitat.—Growing half buried in the ground in sandy soils.

Type species, Scleroderma tinctorium (Mich.) Pers.

Distribution.—Europe; North America; East Indies; Africa; Australia; New Zealand.

The genus contains but two, or possibly three, valid species. Of these, *P. tinctorius* has a distribution similar to that of the genus; *P. microcarpus* is confined to Australia; and *P. Boudieri* (*Polysaccum Boudieri* Lloyd, *Myc. Notes*, 1904, p. 184) is confined to the Island of Corsica. Dehiscence proceeds from the apex downwards (as does maturation of the gleba) so that old specimens are

often represented by the persistent sterile base alone. The persistent tramal plates of the gleba are characteristic and during development of the plant enclose the hymenial layer, which consists of a delicate layer of hyphae lying next the tramal plate wall, and an irregular layer interior to this composed of basidia (pear-shaped or somewhat clavate) bearing 4–6, practically sessile spores. The development has not yet been studied, so that particulars are not available.

1. PISOLITHUS TINCTORIUS (Micheli ex Persoon) Coker and Couch.

Gasteromycetes of E. United States and Canada, 1928, p. 170.—? *Scleroderma herculaneum* (Pall.) Pers., *Syn. Meth. Fung.*, 1801, p. 151.—*S. tinctorium* (Mich.) Pers., *l.c.*, p. 152.—*Pisolithus arenarius* Alb. et Schw., *Conspectus*, 1805, p. 82.—*Polysaccum crassipes* DC. et Desp., *Rapp. voy. bot. Fr.*, i, 1807, p. 8.—*P. acaule* DC., *Fl. Fr.*, v, 1815, p. 103.—*Pisocarpium clavatum* Nees, *Syst. u. Pilze*, 1816, p. 138.—? *Polysaccum herculeum* (Pers.) Fr., *Syst. Myc.*, iii, 1829, p. 52.—*P. turgidum* Fr., *l.c.*, p. 53.—*P. olivaceum* Fr., *l.c.*, p. 54.—*P. Pisocarpium* Fr., *l.c.*—*P. tuberosum* (Mich.) Fr., *l.c.*, p. 55.—*P. conglomeratum* Fr., *l.c.*—*P. arenarium* (Alb. et Schw.) Cda., *Icon. Fung.*, ii, 1838, p. 24.—*Polysaccum tinctorium* Mont., *Phyto. Canariensis*, 1840, p. 87.—*P. australe* Lev., *Ann. Sci. Nat.*, ser. 3, ix, 1848, p. 136.—*P. marmoratum* Berk., *Journ. Linn. Soc.*, Bot., xiii, 1872, p. 155.—*P. leptothecum* Reich., *Reise Oesterr. Freg. Novara um d. Erde*, i, 1870, p. 134.—*P. boreale* Karst., *Not. Faun. et Flor. Fenn.*, viii, 1882, p. 203.—*Pisolithus crassipes* (DC.) Schroet., *Krypt. Fl. Schles.*, iii, 1889, p. 706.—*Scleroderma umbrina* Cke. et Mass., *Grev.*, xix, 1890, p. 45.—*Polysaccum album* Cke. et Mass., *Grev.*, xx, 1891, p. 36.—*P. Pisocarpium* var. *novo-zelandica* P. Henn., *Engl. Jahrb.*, xviii, 1894, p. 37.—*Pisolithus tinctorius* (Mont.) Fisch., *Nat. Pflanzenfam.*, i, 1900, p. 338.—*P. australis* (Lev.) Fisch., *l.c.*—*P. marmoratus* (Berk.) Fisch., *l.c.*—*Polysaccum pusillum* Pat. et Har., *Jour. de Bot.*, xvii, 1903, p. 13.—*P. umbrinum* (Cke. et Mass.) Lloyd, *Lyc. Aus.*, 1905, p. 13.—*Pisolithus Kisslingi* Fisch., *Mitt. Nat. Ges. Bern.*, x, 1906, p. 10.

Plant variable in size and shape, from 3 to 18 cm. tall, to 10 cm. diameter, with or without a stout rooting base. Peridium a single layer, at first smooth, shining and pallid white or ochraceous, becoming brown or black, finally breaking away irregularly from the apex. Gleba divided into polygonal or lenticular chambers, which are larger above and peripherally, unequal in size and shape, dissepiments carbonous, firm but brittle; chambers occupied with the pulverulent spore mass, ranging in colour from ochraceous to umber-brown, sometimes tinted purple. Spores globose, 7–12 μ (commonly 7–9 μ) diameter; epispore thin, 0·5 μ, ferruginous, covered with densely packed spines which may attain a length of 1·5 μ.

Type Locality.—Europe.

Distribution.—Europe; North America; Africa; East Indies; Australia; New Zealand.

Queensland: (Cooke, *Hdbk. Aus. Fungi*, 1892, p. 243, as *Scleroderma umbrina*, *Polysaccum Pisocarpium*, *P. australe* Lev. and *P. album*). Moreton Bay, 6/12*.—New South Wales: Kurrajong Mt., 8/12*; Northbridge, Sydney, 4/16*; Narrabri, 6/19*.—Victoria: (Cooke, *Hdbk.*, 1892, p. 244, as *P. crassipes* and *P. album*); Ararat, E. J. Semmens*.—South Australia: Overland Corner, 12/13*; Mt. Lofty, 7/14*, 6/17*, 7/24*; Belair, 6/20*; Eagle-on-Hill, 4/21*; Kuitpo, 5/21*; Beltana, 8/21*; Fullarton, Adelaide, 5/21*, 1924*, 4/25*; Tunkalilla*; Lake Wangany,

* An asterisk denotes that the collection is in the herbarium of Dr. J. B. Cleland, Adelaide; and where no collector is mentioned, signifies that the collection was made by Dr. Cleland himself.

5/23*; Pearson Island, 1/23*.—Western Australia: Narrogin, 8/26*; South Perth, 8/26, W. M. Carne.—Tasmania: (Lev., *l.c.*, as *P. australe*); no locality, L. Rodway.—New Zealand: Auckland, Whakarewarewa, 2/27, J. B. Cleland, G.H.C.; Geyser Valley, Wairekei, 8/30, 2/31, G.H.C.

This species is abundant in Australia, and is the only one found elsewhere (excluding the doubtful *P. Boudieri*). In New Zealand it is confined to the thermal regions of the North Island. The species is extremely variable as to size and shape, size of the cavities and colour of the gleba, and nature of the exterior of the peridium. All these variations appear to have been named at one time or another, but in the numerous collections examined, I find it is not possible to separate any one owing to the numerous intermediate forms which occur. Hollos (*Gast. Ungarns*, 1904, p. 133) has shown that the eight species named by Fries are all forms of this one. The prevalent form is pyriform in shape, and possesses a firm, black, well-developed rooting base. The peridium is exteriorly typically dark (though white or pallid ochraceous when immature) and smooth, but rugulose forms occur, especially in specimens in which the peridium is thin. *Polysaccum album* was based on a form with this pallid coloured peridium. When these white immature plants are bruised, pigmentation occurs, and if this is more or less arranged in the form of areolations, the plant assumes the appearance of the plant named *Polysaccum marmoratum*. The stem-like base is typically well developed, but is sometimes scanty or wanting (even in individuals of collections possessing strongly developed bases) and then becomes identical with the form named *Polysaccum tuberosum*. Those forms with strongly developed bases were named *P. crassipes*. The gleba in young plants is usually ochraceous, but as the plant ages it changes to ferruginous, and finally to umber-brown. *Scleroderma umbrina* was based on this last condition. The spores are commonly 7–9 μ in diameter; but forms with spores to 12 μ are quite common. The epispore is covered with closely compacted spines which may attain a length of 1·5 μ. Certain species have been recorded as possessing smooth spores, which is probably an error, for smooth spores are not known to occur with certainty in the genus, or indeed in the family.

This species was for many years known as *Polysaccum crassipes* (disregarding the numerous synonyms proposed by Fries) or *P. Pisocarpium*. But Schroeter (*Krypt. Fl. Schles.*, 1889, p. 704) and Hollos (*Gast. Ungarns*, 1904, p. 133) have shown that it possessed a prior name in *Pisolithus arenarius*. Then Lloyd (*Lyc. Aus.*, 1905, p. 13), accepting the synonymy given by Hollos (in which *Scleroderma tinctorium* Pers. was listed), pointed out that the specific name could quite well be that used by Persoon (which was based on the fact that the plant contained a yellow pigment used by the peasants of Europe as a dye), apparently overlooking the fact that it had been used by Montagne for a plant from the Canary Islands (*Polysaccum tinctorium* Mont.) or by Fischer in the combination *Pisolithus tinctorius* (Mont.) Fisch. Coker and Couch accordingly listed the species as *Pisolithus tinctorius* (Pers.) Coker and Couch, which is in keeping with the Rules of Botanical Nomenclature. The plant may have a prior name, since Persoon on a previous page of his *Synopsis*, described as *Scleroderma herculaneum* a plant which was cited by Fries doubtfully as *Polysaccum herculeum*.

2. Pisolithus microcarpus (Cooke and Massee), n. comb.

Polysaccum microcarpum Cke. et Mass., *Grev.*, xvi, 1887, p. 28.—*P. australe* Cke. et Mass., *Grev.*, xvi, 1887, p. 29; non Lev. 1848.—*P. confusum* Cke. et Mass., *Grev.*, xvi, 1888, p. 76.

Plant often with 2-3 peridia attached to the same well developed rooting base, to 10 cm. tall, 3 cm. diameter. Peridium pyriform, smooth or with raised areas corresponding with the glebal cavities, shining and black, this condition extending to the rooting base, which is black, woody and basally divided into numerous coarse rhizoids. Gleba ochraceous or pallid ferruginous-brown in mass, dissepiments carbonous, thin and decidedly brittle; chambers polygonal and closely compacted, less than half the size of those of *P. tinctorius*. Spores globose, 5-7 μ diameter; epispore 0·5 μ thick (including verrucae), pallid ferruginous, finely and somewhat sparsely verruculose.

Type Locality.—Toowoomba, Queensland.

Distribution.—Australia.

Queensland: Toowoomba (Cke. et Mass., *l.c.*); Stradbroke Island, Moreton Bay, 9/19*.—Victoria: (Cke., *Hdbk. Aus. Fung.*, 1892, p. 243 as *Polysaccum confusum* and *P. microcarpum*).—New South Wales: North Shore Line, Sydney, 4/14*; Sydney*; no locality* (2 collections).—Tasmania: Flinders Island, Bass Sts., 11/12*.

This is a distinct species characterized by the low specific gravity of the plant, the black shining exterior of the unopened peridium and rooting base, pallid ochraceous gleba, exceedingly fragile dissepiments and small spores. The latter are finely verruculose, and not covered with the coarse spinous processes of the preceding species.

The plant was first named as *Polysaccum microcarpum*, then in the same work on the following page it was again named as *Polysaccum australe*. As this latter name was preoccupied, being applied by Leveille many years previously to a plant from Australia (now known to be *P. tinctorius*), Massee changed it to *Polysaccum confusum*. The spores were stated to be smooth!

Doubtful Species.

Polysaccum? degenerans Fr., *Pl. Preiss*, ii, 1847, p. 139.—This was recorded by Cooke (*Hdbk. Aus. Fung.*, 1892, p. 245) from Swan River, Western Australia. As the plant was collected associated with *Scleroderma flavidum* (misnamed *S. Geaster*) it is probably a weathered form of that species.

EXPLANATION OF PLATE XVII.

Fig. 1.—*Pisolithus tinctorius.* × ⅔.—Two small forms, the one on left showing the mottled condition not uncommon on unopened plants; that on the right sectioned to show the large cavities of the gleba and the sturdy rooting base.

Fig. 2.—*Pisolithus tinctorius.* × ⅔ approx.—A rooting base of a weathered specimen showing the persistent nature of the carbonous dissepiments of the gleba and the strong development attained by the rooting base in certain plants.

Fig. 3.—*Pisolithus microcarpus.* × ⅔.—Typical plant in centre; on right, caespitose form; on left, section showing the small glebal chambers and fine fragile dissepiments.

Fig. 4.—*Pisolithus tinctorius.* Spores × 750.

Fig. 5.—*Pisolithus microcarpus.* Spores × 750.

Photographs by H. Drake. Spore drawings are original and were prepared with the aid of a projection apparatus from lactic acid mounts.

NOTES ON AUSTRALIAN DIPTERA. XXIX.

By J. R. MALLOCH.

(*Communicated by Dr. G. A. Waterhouse.*)

(Two Text-figures.)

[Read 26th August, 1931.]

In this paper I present a résumé of our knowledge of the Australian members of the family Piophilidae with the description of a new species, the description of a very striking new genus and species of Helomyzidae, and some data on certain genera of Tachinidae with descriptions of two new species of the genus *Palpostoma* Robineau-Desvoidy. The recorded occurrence of the genus *Catharosia* Rondani is also dealt with on the basis of the material upon which it was included in the Australian list.

Family PIOPHILIDAE.

There are but two genera of this family recorded from Australia, *Piophila* Fallen and *Chaetopiophila* Malloch. The two species of the former that have been found here have been placed in different subgenera by Duda, *casei* Linné being the genotype of *Piophila*, sens. str., and *contecta* Walker has been referred by that author to *Protopiophila* Duda of which the type is *latipes* Meigen. *Piophila* is distinguished from other subgenera by the microscopically granulose or alutaceous mesonotum with its three widely separated series of microscopic hairs on the disc, one pair of dorsocentrals, and no presutural. *Protopiophila* has the mesonotum rather evenly haired and with four pairs of dorsocentrals, the anterior two pairs very short and fine and hardly distinguishable from the surrounding hairs.

Genus PIOPHILA Fallen.

PIOPHILA LATIPES Meigen.

I recorded this species in a preceding paper in this series (These PROCEEDINGS, 50, p. 316) but afterwards, when Duda distinguished the Australian and European forms on certain characters of the bristling of the thorax and the structure of the fore tarsi, I changed my determination to *contecta* Walker, described from Australia. However, I have since come into possession of specimens from North America and have also received from Dr. Duda a specimen of the European *latipes* and can find no distinctions in characters that would justify me in accepting the specimens from the three regions as distinct species. The European species has not previously been recorded as occurring in North America and with this additional information the distribution of the species is now extended to include Australia as well as that continent and Europe.

As the species are carrion feeders this distribution is to be expected and it is not at all unlikely that other species of the genus may be found in Australia, especially on dead animals found on the seashore. Quite a large percentage of species occur in both the Nearctic and Palearctic regions.

Genus CHAETOPIOPHILA Malloch.

In distinguishing this genus from *Piophila* I made use of the presence of a pair of quite well developed bristles on the anterior margin of the interfrontalia in addition to four pairs of dorsocentrals, but made no mention of the flattened and haired dorsal surface of the scutellum. With the acquisition of a second specimen, apparently of a new species, I am inclined to consider this last character generic.

There are some striking differences between the genotype and the new species now before me, but the former is known to me from a single female specimen while the other is represented by one male. It is hardly possible that the distinctions in colour and structure are due to sexual dimorphism, and I accept them as distinguishing two species pending the discovery of additional material. The synopsis presented below will serve to distinguish the species.

A. Wings without outstanding bristles on costa, with the usual closely placed fringe of minute setulae; pleurae entirely fulvous yellow; scutellum subtriangular, the apex narrowly rounded and without warts at bases of the apical bristles, the sides slightly carinate basally; hind legs fulvous yellow; bristles of the thorax well distinguished from the hairs .... *hyalipennis* Malloch

AA. Wings with outstanding black bristles from before apex of auxiliary vein to near apex of second, those at end of first vein longer than diameter of costal vein; sternopleura black except on upper margin; scutellum elongate triangular, narrowly transverse at apex, and with a wart at base of each of the apical bristles, the sides quite sharply carinate on entire extent; fore and hind femora and tibiae largely blackened; bristles on anterior portion of thorax hardly distinguishable from the long blackish hairs .... *scutellata*, n. sp.

CHAETOPIOPHILA SCUTELLATA, n. sp.

♂. General colour similar to that of the genotype, shining dark fulvous yellow, a black mark on each upper angle of frons and one over ocelli, all of which extend downward over back of head to a slight extent; third antennal segment and apices of palpi black. Thorax with three quite broad black vittae, the short vittae on each side behind suture which are evident in the genotype are indistinguishable here, but the sternopleura is black except along upper margin and the postnotum is black. Abdomen glossy-black. Legs with most of fore femora and tibiae and apices of hind femora blackened. Wings clear. Halteres brownish-yellow.

Structurally similar to the genotype except in being larger, and having the scutellum longer and more distinctly carinate on upper lateral margins, and the wings with outstanding costal bristles. The legs have very much longer and more dense hairs on all segments than in the genotype, but this may be a sexual character. Length, 5 mm.

Type, Botany Bay, N.S.W. (H. Petersen).

The type was lent to me for description by Dr. Aldrich of the United States National Museum, and it will be deposited in the collection of the Museum.

Nothing is known of the larval habits of this genus, but the larvae of *Piophila* may be found commonly in carrion and decaying animal matter or even preserved meats or cheese and it is probable that those of *Chaetopiophila* will be found to have similar habits. The flies frequent flowers and are readily taken by sweeping. Most of the species of *Piophila* are northern in their occurrence and are, as already noted above, very frequently taken on the seashore or the banks of rivers, and especially near dead animals.

Family Helomyzidae.

In a recent revision of the New Zealand species of this family I have given to the group a much broader scope than given to it by Hendel and Czerny in recent works on the Palearctic and world's faunas respectively. I felt in doing so that it was the only course to pursue as, unless I broadened the definition and therefore the scope of the family, I would necessarily have to increase the number of families, and, as the latter is already entirely too great, I preferred to adopt the former course. In doing so I was compelled to drop the family name Trichoscelidae recently accepted by Hendel, and many of the New Zealand forms and also those of South America, as well as a few at present known to me from Australia which would fall more or less definitely into that group, are according to my present method component parts of Helomyzidae. One of those genera is described herein and it departs from the generally accepted type of Helomyzidae even more than do the more typical Trichosceline forms. In fact, it is at present unique in the structure and armature of the frons. The lack of well developed costal bristles is not exceptional as there are several genera accepted without question as belonging to the family in which these are either undeveloped or very poorly so. The small size of the dorsal preapical bristle of the tibiae is worth noting, but this character is rather variable.

Genus Cairnsimyia, n.g.

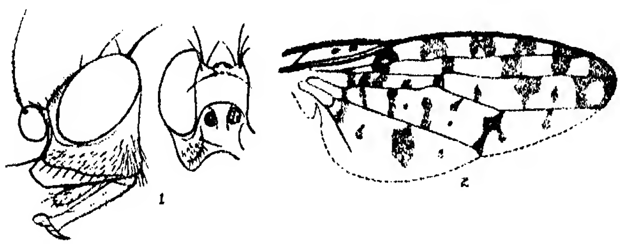
Generic characters.—Frons very distinctly depressed on upper half, at vertex with an almost V-shaped excavation, the posterior ocelli well forward of the hind margin of eyes and almost in line with, or slightly in front of, the single upper orbital bristle on each side, which is about one-fourth from hind margin of frons when viewed from above; two strong vertical bristles situated rather high on each side of vertical cavity; postverticals and postocellars lacking; ocellars quite long, situated on each side of anterior ocellus and directed laterally; frons longer than wide, narrowed near hind margin; profile of head as in Text-figure 1; aristae bare; antennae rather widely separated, the space between their bases flattened; centre of propleura and the prosternum with fine short hairs; propleural bristle present; mesopleura without bristles, except a fine one on centre of hind margin; sternopleura with three or four upper marginal bristles; dorsocentrals one pair; scutellum haired on disc, with four marginal bristles. Wings with the auxiliary vein running very close to first vein apically but not connected with it; costa without bristles, ending at apex of fourth vein; sixth vein ceasing a short distance from margin of wing. Legs normal, the preapical dorsal bristle very small.

Genotype, the following species.

Cairnsimyia cavifrons, n. sp.

♂, ♀. Clay-yellow, slightly shining, with brown or fuscous markings. Head with brown dusting which is changeable on frons according to the angle from which it is viewed; face blackish on centre, especially below and on labrum; third antennal segment darkened on upper margin. Thorax with yellowish-brown dusting, mesonotum with five reddish-brown vittae, the central three broken and more or less connected on part of their courses, the sublateral pair broader and usually complete, notopleural suture brown; pleura with more golden dusting and with a reddish vitta across mesopleura, the scutellum with two brown spots on base. Abdomen with each tergite broadly brown at base. Each tibia with two brown annuli. Wings with many dark marks (Text-fig. 2).

Eyes bare, frons with some fine black hairs. Mesonotum with rather closely set short decumbent dark hairs, one humeral, two notopleurals, one supra-alar, two postalars, one pair of dorsocentrals and one pair of acrostichals before scutellum. Abdomen ovate; hypopygium of male complex. Femoral bristles very



Text-fig. 1.—Head of *Cairnsimyia cavifrons* from the side, and from in front (partial).
Text-fig. 2.—*Cairnsimyia cavifrons*, wing.

fine, noticeable only on the fore pair; mid tarsi in both sexes with some short stout black bristles at apices of the segments below. Length, 5 mm.

Type, male, allotype, and two paratypes, Cairns, Queensland, and Kuranda, Queensland, from the Lichtwardt collection in the Deutsches Entomologisches Institut, Berlin.

A paratype will be sent to the Australian Museum through the kindness of Dr. Walther Horn, director of the institute which owns the material.

Family Tachinidae.

Genus Catharosia Rondani.

In my Catalogue of this family published in a preceding paper of this series I have listed a species of this genus described by Curran, *varicolor*, from Australia. I have recently been able to examine two paratypes, a male and female, in the United States National Museum and state definitely that the species does not belong to *Catharosia*. The latter has at least one distinct bristle on the central part of the propleura, the lower calypter is narrow, and rounded at apex, and the female has the ovipositor prong-like. In Curran's species the centre of the propleura is bare, the lower calypter is large, widened apically, and almost transverse at apex, and the ovipositor of the female is stout and curved forward below abdomen. The only character that might cause one to associate the Australian species with *Catharosia* is the venation of the wing, both genera having the first posterior cell closed at a considerable distance from the margin of the wing, and with a long straight petiole. I have examined the genotype of *Catharosia* and those of certain closely related genera and find them in agreement in the three essential characters listed above.

Merely to point out the erroneous placement of *varicolor* is insufficient reason for this note, and I desire to indicate that the species belongs to a genus very close to *Hyalomyia*, as is proven by the lack of strong dorsal bristles on the abdomen, the general structure of both sexes, the wing venation, and the large

lower calypter. There is a puparium mounted with the male which I have seen here and this agrees closely with that of American species of *Alophora* Robineau-Desvoidy (= *Hyalomyia*) described by C. T. Greene, and others of the same genus seen by me from India. It is possible that the genus *Austrophasia* Townsend may be utilized for the reception of *varicolor*, as it agrees very well with *rufiventris* Macquart, the genotype, but it is evidently distinct specifically from the latter.

The host of *varicornis* is *Dysdercus sidae* which is also the host of *Alophora auriventris* Curran described on the same page as the former. As far as known all the species of the group attack Hemiptera; the host of *Catharosia* is unknown.

Genus Macropia Malloch.

In a recent letter from Dr. C. H. T. Townsend acknowledging receipt of my papers on Australian Tachinidae he informed me that this genus was probably synonymous with *Anaperistommyia* Townsend. An examination of the genotype of the latter proves that this suggestion is correct. At the same time I examined the genotype of *Halidaya* Egger, and the only distinction between that genus and the first one that I could discover consisted of the lack of setulae on the fifth wing-vein on its upper surface. I am not inclined to accept this as a generic character and in all probability the genera will be accepted as synonymous in any comprehensive treatment of the family. In fact Bezzi has included species with setulose and bare fifth veins in his key to the species of *Halidaya* (*Bull. Ent. Res.*, 16, pt. 2, 1925, p. 121). Townsend in his original description of *Anaperistommyia* (*Suppl. Ent.*, No. 14, 1926, p. 15) cited as his genotype *optica*, n. sp., and stated that this was identical with the species described by Bezzi under the name *Halidaya luteicornis* Walker. He stated that the species described by Walker was probably distinct from that identified as it by Bezzi, but gave no specific reason for the opinion except in citing the localities, Walker's species being from Gilolo and the other from Sumatra. Townsend gave *H. argentea* Egger as probably congeneric with *optica*. The latter is European, and is most closely similar to the Australian species in colour characters. It will be necessary to make a careful comparative examination of Australian and European examples to determine their status. Bezzi placed the genus *Halidaya* in the subfamily Thelairinae and recorded the host of *H. luteicornis* Walker (*optica* Townsend) as *Parnara mathias*, and its occurrence in Malacca, Seramban, and Taiping, Federated Malay States. He also stated that he had seen examples from Canton and Hangchow which are in the collection of the United States National Museum. The genus *Halidayopsis* Townsend (*Ent. Mitt.*, 16, 1927, 282) is very closely related to this one, but I have not seen the genotype.

Genus Palpostoma Robineau-Desvoidy.

Palpostoma armiceps, n. sp.

♀. Head testaceous yellow, with whitish dust which is most distinct on the frontal orbits and parafacials, aristae brownish, hairs and bristles fuscous, a few below posterior margin of mouth opening yellowish. Thorax rather darker coloured than head with the mesonotum almost entirely infuscated and grey-dusted, the usual four vittae dark-brown but not conspicuous; pleura with fuscous marks covering almost all of sclerites except propleura, dusted like the mesonotum. Abdomen coloured as the thorax, but more noticeably grey-dusted and the dorsum

with dark-brown dots at bases of the hairs and bristles which are less fused on the third visible tergite than on those anterior to it. Legs tawny-yellow. Wings greyish-hyaline, veins yellowish. Calyptrae whitish. Halteres yellow.

Frons at narrowest point not wider than third antennal segment, much widened to anterior margin, the orbits separated and with numerous short strong hairs and a series of bristles along inner margins; verticals short and fine, not longer than the ocellars; no forwardly-directed orbitals present; parafacials at base of antennae a little wider than third antennal segment, with very short but stout black setulae, and about half as wide as height of cheek, the latter with many spine-like bristles adjacent to the rather short stout vibrissa; third antennal segment about three times as long as second; palpi moderately long; proboscis with the apical section about as long as palpi and the palpi-like apical processes distinct in type. Thorax with the usual bristles, but the anterior intra-alar long, the sternopleurals 1 + 1, and some fine erect dark hairs on lower margin of anterior spiracle; sides of scutellum haired on entire extent anteriorly, apex slightly emarginate. Abdomen conical, lateral bristles on all tergites, second visible tergite with a pair of central apical bristles, third with a complete series of apical bristles which are much stronger than those on the fourth tergite. Fore tibia with one or two posterior submedian bristles; mid tibia with the ventral bristle very short; hind tibia with two anteroventral bristles. First posterior cell of wing with the petiole more than half as long as inner cross-vein; outer cross-vein sinuate, connecting with fourth vein about two-thirds from inner cross-vein to bend of fourth. Length, 10 mm.

Type, Townsville, Qld., no other data (F. H. Taylor). In United States National Museum. Lent to me for description by Dr. J. M. Aldrich.

PALPOSTOMA SUBSESSILIS, n. sp.

♂, ♀. Differs in colour from the preceding species in having the mesonotum almost without infuscation, and less noticeably whitish dusted, the vittae appearing less dark and dividing the dust anteriorly but not as distinctly posteriorly, the male having the dust on the greater portion of the postsutural portion more yellowish than whitish; pleura unspotted. Abdomen with a trace of a dark dorsocentral vitta anteriorly, and the third and fourth visible tergites largely dark brown, with greyish dusting, and dark dots at bases of the hairs and bristles.

Differs structurally from *armiceps* in having the frons of the female narrower, distinctly narrower than the third antennal segment, that of the male practically linear, the bristles adjacent to the vibrissae not nearly as strong, and the anterior thoracic spiracle bare below. Most of the specimens have a short bristle on the anterodorsal surface of the fore tibia beyond its middle, and there is usually a weaker lower anterior sternopleural bristle present. The first posterior cell of the wing is usually closed just at the margin of the wing and more rarely it is very short petiolate, the petiole being almost indistinguishable except with a high power lens; the outer cross-vein is not beyond midway from inner cross-vein to bend of fourth, but usually noticeably nearer to the cross-vein than to the bend. In other respects very similar to *armiceps*. Length, 8–10 mm.

Type, female, Sydney, N.S.W., 2.12.1923; allotype, topotypical, 1.1.1924; paratypes, topotypical, various dates in November, December, and January, 1923-24 (Health Dept.); five specimens Woy Woy, various dates in September, 1930 (R. W. Burrell), reared from puparia in abdomen of host, a scarabaeid beetle.

Last-mentioned five specimens in United States National Museum.

Genus Prosena St. Fargeau and Serville.

Mr. C. H. Curran has recently added two new species to the Australian list and I present below the references.

Prosena variegata Curran.

Ann. Ent. Soc. Amer., 22, 1929, p. 509.

A large species, 10–12 mm. in length, with the frontal vitta obsolete above in the male, the legs very long and reddish, with the tarsi black. Lacking many of the details used in my recently published key to the Australian species of the genus and without information as to the bristling of the mid tibia and structure of the hypopygium, it is impossible to determine whether this species was in the material which I had before me.

Locality, Gravesend, Queensland, J. Mann.

Female not described.

Prosena varia Curran.

Ann. Ent. Soc. Amer., 22, 1929, p. 509.

This species is darker in colour than the preceding one, with the legs black and only the tibiae reddish, but the structural details are even less satisfactorily dealt with and, as in the other case, it is impossible to place the species in my key. Length, 9 mm.

Locality: New South Wales. Schrader.

No information is given as to the disposition of the type specimens.

Genus Delta Malloch.

This generic name was used in my preparation of the manuscript of a recent paper on the family as a tentative appellation and unfortunately was allowed to go through the press as the name of the genus (These Proceedings, 55, 1930, p. 332). The name is preoccupied by *Delta* Saalmuller in Insecta and I propose to replace it with *Deltomyza* n.n.

Genus Voriella Malloch.

The genotype cited (These Proceedings, 55, 1930, p. 335), *recedens*, n. sp., is a tentative name for *uniseta* which was not changed when the manuscript was finally checked for the printer.

Genus Apilia Malloch.

In a recent letter Dr. C. H. T. Townsend informs me that this genus is very close to, if not identical with, *Neophryxe* Townsend.

The genotype of the latter is in the collection of the United States National Museum and an examination discloses the fact that it has prosternal setulae which are, as indicated in my original description of *Apilia*, lacking in my genotype.

ON THE AUTECOLOGY OF *STIPA NITIDA*, A STUDY OF A FODDER GRASS IN ARID AUSTRALIA.

By T. G. B. OSBORN, Professor of Botany, University of Sydney,
J. G. WOOD, Lecturer in Botany, University of Adelaide, and
T. B. PALTRIDGE, Field Officer, C.S.I.R.

(Plate xviii; fourteen Text-figures.)

[Read 26th August, 1931.]

I. INTRODUCTION.

The genus *Stipa* belongs to the tribe Agrostidae of the family Gramineae and different species are found on the plains and arid-steppe regions of both hemispheres where they form an important part of the forage. They are commonly termed "Spear grasses" on account of the sharp pointed "seed" which has a long, usually tightly twisted awn.

Stipa nitida S. & H. is the common spear grass in South Australia within the area bounded by the 8-inch isohyet. It is the most important fodder grass for sheep and is one much sought after by these animals. The investigation to be described in this paper was undertaken primarily to discover the effect of grazing and enclosure upon this grass, but the work has developed into a more detailed study of the autecology of the species.

The research was carried out at the Koonamore Vegetation Reserve (Osborn, 1925), an area of 1260 acres protected by rabbit- and sheep-proof fencing. This reserve is situated in saltbush-plain country in the north-east of South Australia. It forms, together with the laboratory adjacent, the Arid Flora Research Station of the University of Adelaide. Work at the centre was initiated by one of us in 1926. Since March, 1928, it has been carried on with the aid of a grant from the Commonwealth Council for Scientific and Industrial Research. This has enabled the scope of the work to be extended and made it possible to station a Field Officer at the Reserve. The first-named author desires to express his gratitude to the Council for Scientific and Industrial Research for their generous assistance. He also wishes to thank the Council of the University of Adelaide for the facilities afforded him at Koonamore subsequent to his departure to the University of Sydney.

The Koonamore Vegetation Reserve is situated about forty miles north of the railway station of Yunta on the Broken Hill-Peterborough line, at an altitude of about 650 feet. The average rainfall at Koonamore Head Station, four miles distant from the Reserve, over a period of forty years, is 8·42 inches.

II. THE STATUS AND DESCRIPTION OF STIPA NITIDA S. & H.

Considerable confusion has surrounded the status of the species in question. It was originally known as *Stipa scabra* Lindl. var. *auriculata* J. M. Black, but on revision of the Australian members of the genus (Hughes, 1921) it was found that *Stipa scabra* Lindl. of Black's "Flora of South Australia" was in reality *Stipa*

scabra Benth. *partim*, and the species was renamed *Stipa variabilis* Hughes. On page 15 of the Kew Bulletin, 1921, *Stipa scabra* Lindl. var. *auriculata* J. M. Black is given as a synonym of *Stipa Drummondii* Steud. which Miss Hughes mentions as being closely allied to *Stipa variabilis* Hughes.

In further work on the Australian Stipas (Kew Bulletin, 1922) *Stipa Luehmannii* Reader is given as a synonym of *Stipa Drummondii* Steud., and on page 670 of Black's "Flora of South Australia (Additions and Corrections)" *Stipa Luehmannii* Reader and *Stipa horrifolia* J. M. Black are given as synonyms of *Stipa Drummondii* Steud. Black previously ("Flora of South Australia", p. 66) had considered that his *Stipa horrifolia* might prove to be a dry country form of *Stipa Luehmannii* Reader. These species are obviously different from *Stipa scabra* Lindl. var. *auriculata* J. M. Black.

In the Kew Bulletin, 1927, Summerhayes and Hubbard published a description of *Stipa nitida* S. & H. which is the species in question and of which *Stipa scabra* Lindl. var. *auriculata* J. M. Black is a synonym.

The plant in question is usually erect, varying in height from a few centimetres to about 50 centimetres, with stems about 2 millimetres thick and with glabrous or scabrous-pubescent leaves. The leaf-blades are involute-filiform, 5–20 centimetres long; the lower sheaths are also pubescent. The ligule is very short, ciliate and extended into a conspicuous auricle on one side.

The panicle is loose, unilateral, 10–30 centimetres long, pale-green and shining, and is soft and silky to the touch, the rachis and branches being minutely pubescent. The outer glumes are narrow, hyaline and subequal, the lower one being 10–12 millimetres long, 3-nerved near the base and the other one rather shorter and sub-5-nerved. The flowing glume is narrow, white-pubescent, and 4–6 millimetres long with the callus. The awn is capillary, much-curved, about 6 centimetres long and is minutely pubescent.

The plants do not form a sward, but occur as scattered individuals forming fairly dense tussocks in sandy soils or wherever the soil is suitable in other communities. Under more favourable conditions with better water-relations and with better establishment the plant is a perennial, but usually tends, under the rigorous summer conditions of arid Australia, to become an annual. This point will be considered in greater detail under "Germination". Plate xviii, fig. 1, shows well the habit of the grass and the character of a flourishing community on sandy soil. The tussock form of the plant is illustrated in Plate xviii, fig. 2, where also grazed stumps are visible. In Plate xviii, fig. 3, is shown a community of plants killed by the drought of 1929.

III. Methods and Errors of Methods.

Two methods have been utilized in the investigations. First, that of permanent quadrats set out and first surveyed in May, 1926. These quadrats are 100 square metres in area, the sides being 10 metres. They have been charted every three months from April, 1926, to the completion of this work in 1931. The results of the quadrat studies will be given in a later section.

For the study of the effect of the biota upon spear grass, we have used a second method which has proved successful. Thirty-one posts at approximately equal intervals around the four fences of the Reserve have been numbered and taken as observation posts. This gives 124 observation posts in all, and since the numbered posts are to be found on every soil type which occurs around the fence, readings from these may be considered to give a fair sample of the vegetation of

the area. For the purpose of estimating the vegetation, every three months during the period from May, 1928, to March, 1931, an observer marched 20 paces in a direct line from each numbered post and at right angles to the fence. At the 20th pace the observer dropped a metre-square frame at his feet and recorded the number of *Stipa* plants occurring in the square metre; at the same time records were made of the number of *Stipa* seedlings, the number of "tufts" and "tussocks", the number of dead *Stipa* plants, the soil type, and also the approximate number of other plants which were present. *Stipa* plants with only two or three leaves were classed as seedlings, small compact plants up to about 10 centimetres high with many leaves as "tufts", and mature plants with a well defined tussock habit as "tussocks". Two observers usually worked together, the one inside the Reserve and the other outside. The Reserve has not been stocked since its enclosure, whereas the paddocks adjoining it have been stocked, so that by means of this method an estimate of the effect of sheep grazing on *Stipa nitida* can be obtained.

The length of pace of the three observers varies; and sometimes the metre-square may be dropped on a spot not quite in a direct line with the numbered observation post. It was necessary therefore to get an idea of the probable range of error of our readings. With one or two exceptions, all the counts were made by some pair of the three authors. In August, 1930, independent counts of the *Stipa* plants, both inside and outside the north fence, were made by each of the three of us, and from these numbers the standard deviation of the mean and the range of our error were calculated. These results have given us the fullest confidence in our figures and show that 31 observation posts are sufficient to give us a true sample of the frequencies inside and outside each of the Reserve fences. The individual counts were made at a time when there was present the greatest number of *Stipa* plants which we have found in the course of our investigations. The results are as follows:

	Inside.	*Outside.*
J.G.W.	790	283
T.G.B.O.	804	259
T.B.P.	805	269
Mean	800	270

The standard deviations of these means are:

Inside	800 ± 7
Outside	270 ± 9

The error of counting is greater outside the Reserve where the effect of grazing comes into play and where the plants are more scattered. Here the length of pace of the observer affects the figures more than in the more uniform area inside the Reserve, but the differences are very small. The divergences between the lowest and highest readings of the different observers are 8% outside the fence and 2% inside the fence.

IV. Climatic Factors.

In this section we give data as to the climatic factor during the period covered by this investigation. Only those data relevant to the growth of *Stipa* are given here. We reserve a fuller discussion of the climate for a later communication on the ecology of the district.

Rainfall.

Light falls of rain in an arid region when the soil is dry and dusty do not penetrate the ground to an extent sufficient to reach the roots of the plant. It has

been pointed out by Cannon (1921), Osborn and Wood (1923), and Osborn (1925) that falls of this "ineffective" type are common to much of arid Australia and that they render the figures for the total annual rainfall unreliable as a true indication of the value of rainfall to the vegetation.

Cannon (1921) considered 15 points of rain to be the minimum effective rainfall if it fell during a dry period. We consider this figure to be rather low and from considerable and extended observations think that about 25 points is nearer the minimum amount of rain that is effective during a dry period. Lighter falls do not penetrate the soil more than 2-3 cm.

In Table 1 are given the monthly falls of rain together with the number of rainy days, and days on which more than 25 points fell. All rainfall data are given in points, 100 points = 1 inch.

Our series of observations extended over the period of one of the worst droughts recorded in the north-eastern districts of South Australia. Over the period of 15 months from August, 1928, to October, 1929, only 176 points of rain fell. It will be seen also that there were five consecutive months without any fall of rain at all and ten consecutive months without an effective fall of rain.

The combined effects of drought and stocking on *Stipa nitida* will be analysed later (pp. 314-322).

Temperature.

The temperature in arid Australia, as in other desert and semidesert regions, shows a high diurnal range. The difference between maximum and minimum temperatures is from 30° to 40° F. over practically the whole year. Maximum temperatures are high during the Summer, and from November to March inclusive the average monthly maximum temperature is approximately 90° F. During this period temperatures of 100° F. or higher are frequent.

The temperature reaches its lowest value from the middle of June to the middle of July. The average daily maximum temperature at this time is 63° F., and the average minimum temperature may fall below 32° F. (30·1° F. for July, 1929). Frosts are frequent during June and July, and somewhat less so in August. They are only of occasional occurrence in May and September. The rise in temperature from August to October is rapid, as is also the fall from April to June, so that well marked hot and cold seasons occur. The temperature data for three years are shown in Table 2.

The humidity data are of interest although they do not concern *Stipa nitida* particularly. The average daily maximum humidity for the year is 85%. The average minimum humidity may fall below 35% at any time from September to March inclusive. Our records show that in every month the mean maximum exceeds 80% humidity and that, excluding the winter months, the mean minimum falls below 40%. We are dealing then with a climate of extremes as regards humidity, which during the same twenty-four hour period may be moist but also dry.

Germination of Stipa nitida, *and Duration of the Plant.*

Germination tests of the fruits of *Stipa nitida* have shown that the percentage of germination is low and also that the fruits are exacting in their requirements for germination.

TABLE 1.—RAINFALL DATA.

Table showing mean rainfall at Koonamore Head Station based on records for 27 years, also monthly falls during the years 1926-30, numbers of rainy days and of falls over 25 points (100 points = 1 inch).

Year.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	Mean	70	45	61	64	93	108	46	63	58	81	64	59	812
1926.	Rainfall	0	2	36	64	166	61	24	104	224	0	7	62	750
	Rainy days	0	1	2	3	6	3	6	8	6	0	0	4	39
	Falls > 25 points	0	0	1	1	2	1	0	2	3	0	0	1	11
1927.	Rainfall	62	33	7	0	1	76	26	17	90	8	50	39	409
	Rainy days	4	2	1	0	2	5	5	1	5	4	4	3	36
	Falls > 25 points	1	1	0	0	0	2	0	0	2	1	0	0	7
1928.	Rainfall	1	390	40	0	27	108	103	6	28	0	0	0	703
	Rainy days	1	4	3	0	2	6	5	1	2	0	0	0	24
	Falls > 25 points	0	1	1	0	0	3	2	0	1	0	0	0	8
1929	Rainfall	0	0	15	13	0	9	12	26	62	0	35	327	504
	Rainy days	0	0	1	1	0	1	1	1	2	0	3	3	13
	Falls > 25 points	0	0	0	0	0	0	0	1	1	0	0	2	4
1930.	Rainfall	7	93	0	80	33	0	80	47	90	112	38	108	688
	Rainy days	1	4	0	2	3	0	6	4	3	6	2	3	34
	Falls > 25 points	0	1	0	2	0	0	1	0	2	2	1	3	13

TABLE 2.—TEMPERATURE DATA.

Year.		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1928	Average of daily maxima	—	—	—	—	—	—	58·5	69·6	68·8	75·9	94·0	91·7
	Average of daily minima	—	—	—	—	—	—	36·3	38·7	40·5	47·4	62·0	61·3
	Terrestrial radiation	—	—	—	—	—	—	29·5	36·0	41·0	41·0	60·3	58·3
1929	Average of daily maxima	92·4	—	82·8	87·8	64·7	63·0	57·9	62·5	66·0	80·6	81·0	84·0
	Average of daily minima	57·8	—	54·4	49·6	37·6	34·5	30·1	34·5	32·0	40·0	54·4	51·6
	Terrestrial radiation	57·5	—	51·0	40·2	37·2	32·0	26·5	32·5	27·1	45·6	51·7	45·0
1930	Average of daily maxima	—	90·0	87·6	87·0	59·0	60·8	61·0	69·2	69·3	79·7	87·7	89·3
	Average of daily minima	—	67·6	56·6	43·9	34·5	37·0	39·0	37·2	41·6	50·9	53·3	59·3
	Terrestrial radiation	—	64·4	52·8	44·0	32·0	31·8	34·9	35·0	37·2	43·7	50·2	55·6

At first the fruits were placed in Petri dishes in pure washed sand, with water or KNO_3 solution added, sufficient to bring the sand to 60% of saturation point with water; fifty seeds were planted in each dish. The tests were carried out in a multiple temperature incubator at the following temperatures Centigrade: 4°, 8°, 12°, 15°, 21°, 24°, 31°, 33°, and 38°. One series was tested using distilled water only, and another using 0·5% KNO_3 solution. At each temperature the tests were carried out in triplicate. In addition an alternating series was carried out as follows: (*a*) 8 hours at 33°, followed by 16 hours at 12° each day; (*b*) 8 hours at 38°, followed by 16 hours at 15° each day.

Under these conditions there occurred only a 1% germination at 24° C. No seedlings appeared at any other temperature.

The seeds on examination proved all to contain embryos. The fruits used in the test were obtained from the *Stipa* crop following the rains of February, 1930. Since it was suspected that a "Maturing Factor" might be operative, seeds from the same batch and from a batch collected later were repeated for germination three months later under identical conditions. No germination occurred at any temperature. Immersion in strong sulphuric acid, and in liquid air, and also removal of the glumes all failed to cause germination.

An experiment was now set up to test germination under saturated conditions. Fruits, collected February, 1930, were placed on blotting paper saturated with distilled water in the light on Copenhagen incubators. Under these conditions, seedlings appeared at 24–25° C. (75–77° F.) after two to three days. After 10 days a 28% germination was shown. The optimum temperature range is apparently restricted. Under similar conditions the percentage germination at 20° C. (68° F.) was only 6%.

It is obvious from these experiments that the seeds will only germinate under conditions of saturation of the soil with water. In addition, the seeds are photosensitive. In light at 24° C. the average percentage germination after 10 days was 28; in darkness after the same period the average germination was only 12%. Seeds from the same batch at 28° C. in darkness showed only 2% germination after 16 days but upon being illuminated at the same temperature for three days the germination rose to 12·5%.

Unlike some photosensitive seeds (Gassner, 1930; Morinaga, 1926) alternations of temperature have no effect in increasing the percentage germination, as the following results show:

> Two series of alternating temperatures, 8 hours at 28° C., followed by 16 hours at 20° each day; 50 seeds each in triplicate:
>
> In *light* after 10 days; germination 12·0%.
> In *dark* after 10 days; germination 2·5%.

Light in arid Australia is probably never a limiting factor, but two facts elucidated from the germination tests, namely, the relatively high optimum temperature and saturated soil conditions, explain the incidence of *Stipa* in the arid country. Widespread germination of *Stipa* on Koonamore has always occurred in the hot season (from October to April) when the average temperature does not fall below 80° F., and, secondly, has always followed heavy rainfall as the following table shows:

Germination.	Rainfall.	
September, 1926.	August-September, 1926 ..	3·28 inches
March, 1928.	February, 1928	3·90 inches
February-March, 1930.	December, 1929	3·27 inches

The incidence of rain sufficient to cause germination also has a bearing on the length of life of *Stipa* plants. Analyses of the charts of Quadrat No. 2, a one square metre quadrat on sandy soil charted every three months, give the following data:

Germination.	Died.	Length of Life.
September, 1926.	September-December, 1927.	12-15 months.
April, 1928.	December, 1928.	9-10 months.
March-June, 1930.	December, 1930-February, 1931.	10 months.

In all these cases the plants acted as annuals, although, in the case of plants germinated in September, *i.e.*, at the beginning of the hot season, the plants persisted for 15 months.

On Quadrat No. 1, a one metre quadrat on loamy soil mapped every three months, several grass seedlings were recorded in September, 1926, following the heavy rains of August-September of that year and of these seedlings four can be traced as adult plants through successive mappings to August, 1930. These four plants actually died between the August and December, 1928, mappings but their dried remains persisted until August, 1930, at the end of the drought period when their place was taken by *Bassia patenticuspis*. These plants therefore persisted alive for about 27 months and during this period they flowered twice, first in November, 1926, and secondly in August, 1928. These plants were established early in the hot season (September, 1926) and this early establishment contributed largely to their perennial nature.

Phaenological Data.

The time when the plants reach maturity depends naturally upon the time of appearance of the seedlings. No definite flowering or fruiting period occurs, but these take place at any time from April to January. Normally, when the seedlings follow February rains, the plants begin to flower heavily about August and shed their fruits before December, that is flowering usually occurs towards the end of the cold season and the development of the fruit during the early months of the hot season. The following phaenological records are of interest in this respect.

25-9-26.—Odd plants in flower.
25-5-28.—Odd plants in flower, passing to fruit.
4-9-28.—Plants fruiting.
17-9-28.—Fruiting freely.
26-11-28.—Late fruiting.
8-4-29.—Shooting from base of old plants on "fire quadrats".*
2-10-29.—Large plants on "fire quadrats" have ripe seed.
3-1-30.—Fruiting of plants on "fire quadrats".
31-3-30.—Seedlings appearing.
20-5-30.—Plants plentiful, some large.
15-7-30.—Plants have flowers.
29-7-30.—Flowering and fruiting.
17-8-30.—Flowering and fruiting.

* During the drought year 1929 no green *Stipa* plants were present except on certain "fire-quadrats" where the plants had good water relations, and complete protection from rabbits.

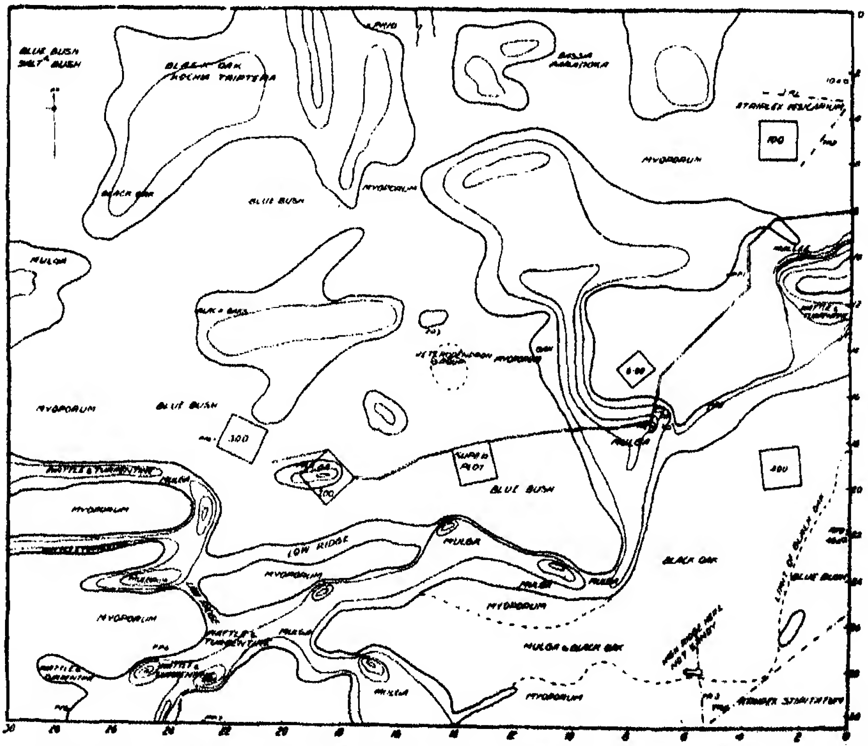
V. Edaphic Factors.

The Soil Types.

That portion of the sheep station of Koonamore on which the Reserve is situated is part of an elevated peneplain encircled by hills. These hills are formed chiefly of Lower Pre-Cambrian gneisses and schists overlain by Upper Pre-Cambrian deposits consisting in the main part of quartzites and a consolidated mudstone, and penetrated frequently by pegmatite dykes. Sometimes the Lower Pre-Cambrian rocks are exposed.

The soils of the plains are derived from these sedimentary and igneous rocks. The drainage of the whole area is internal and the streams and watercourses on and around the Reserve find their way into a large lake in a depression forming the lowest point of the Koonamore basin.

The Vegetation Reserve itself averages about 650 feet in height and is of an undulatory nature. There is a complex system of low sandhills alternating with harder soil on the flats (Text-fig. 1). These flats are silty loam towards the western side and in the centre, but on the eastern side the soil is a hard loam



Text-fig. 1.—Sketch map of the Koonamore Vegetation Reserve based on a prismatic compass survey. The form lines represent approximately 10-foot intervals. The heavier first form line is also a boundary between the sandy and loamy soil types. The position of the quadrat systems and transect lines within the Reserve is shown, also the various permanent photograph points (P.P.). The main vegetation types are indicated on the map. Scale, 1 inch = 500 metres. J.G.W. *fecit.*

mixed with a good deal of nodular travertine limestone. On this latter soil type are developed the dwarf Chenopodiaceous shrublands already described by Osborn and Wood (1923). The sandhill-plain areas carry usually various open scrub communities of which mulga (*Acacia aneura*), wattle (*Acacia Burkittii*), black oak (*Casuarina lepidophloia*), Sandal wood (*Myoporum platycarpum*), turpentine (*Eremophila Sturtii*) and bullock bush (*Heterodendron oleaefolium*) are the most important trees and shrubs.

These soil types, namely, sand and sandy loam, silt flat, and hard loam with travertine limestone, are the three outstanding types on the plains in arid South Australia. Analyses are given in the following tables showing the percentage of the different fractions in the three soil types collected from typical areas in the Reserve.

(*a*). *Soil from sandhills carrying mulga and wattle with Stipa.*

Fraction.	A. 0-9 inches. *Percentage.*	B. 9-18 inches. *Percentage.*
Gravel	Nil	Nil
Coarse sand	63·2	58·6
Fine sand	26·6	28·8
Silt	1·1	0·7
Fine silt	2·2	2·3
Clay	3·6	3·7
Loss on acid treatment	0·7	2·8
Loss on ignition	1·4	2·3
Moisture	1·0	1·0
Totals	99·7	100·2

The profile shows practically no variation, but consists of a buff-coloured coarse sand until the underlying silt is reached. This depth is variable.

The reaction of the soil is alkaline, pH = 8·08.

(*b*). *Soil from silt flat.*

This sample is from a typical silt flat in which the water does not remain for any length of time after rain, but flows away. The percentages of the various fractions are:

Fraction.	*Percentage.*
Gravel	Nil
Coarse sand	14·9
Fine sand	19·7
Silt	6·6
Fine silt	29·2
Clay	16·3
Loss on acid treatment	1·0
Loss on ignition	4·9
Moisture	5·4
Total	98·0

The profile shows a matrix of a uniform buff colour, with pockets, more or less porous, of a chocolate-brown colour. The soil in the pockets is stickier and contains more clay than that of the matrix. The depth of this soil varies, but is uniform in texture usually for several feet. The surface of the silt flats cracks into shallow diapers on drying. The soil reaction is alkaline, pH = 7·73.

These flats after rain carry a wealth of ephemeral plants, but permanent plants are few, the chief species being *Myoporum platycarpum*, *Heterodendron oleaefolium*,

Eremophila scoparia, *Eremophila longifolia*, *Cassia Sturtii*, *Cassia eremophila* and *Lycium australe*.

(*c*). *Hard loam soils with nodular travertine limestone.—"Saltbush soils".*

As indicated above, these soils are typical of the elevated plains (and indeed closely resemble the mallee soils of the wetter areas) and carry a dwarf shrubland consisting chiefly of saltbush (*Atriplex vesicarium*) and bluebushes (*Kochia planifolia* and *K. sedifolia*), the latter species being developed particularly where the soil contains much travertine limestone near the surface. Analysis of the various fractions in a typical soil of this type gave the following results:

Fraction.	*Percentage.*
Gravel	Nil
Coarse sand	55·9
Fine sand	25·6
Silt	2·5
Fine silt	6·1
Clay	5·6
Loss on acid treatment	0·6
Loss on ignition	2·1
Moisture	1·6
	100·0

The travertine nodules were not taken into account in this analysis but were sieved off.

A profile of this soil type is as follows:

0- 3 inches.—Silt and fine sand (cocoa-coloured) with small nodules of travertine limestone.
3-12 inches.—Similar soil with plentiful nodular travertine.
12-21 inches.—Solid crust of travertine limestone.
21-28 inches.—Nodular travertine limestone, fairly small but densely packed.
28-46 inches.—Similar to above fraction, but with a fair amount of small lateritic ironstone nodules.

The reaction of the upper soil, 0–12 inches, is alkaline, pH = 7·81.

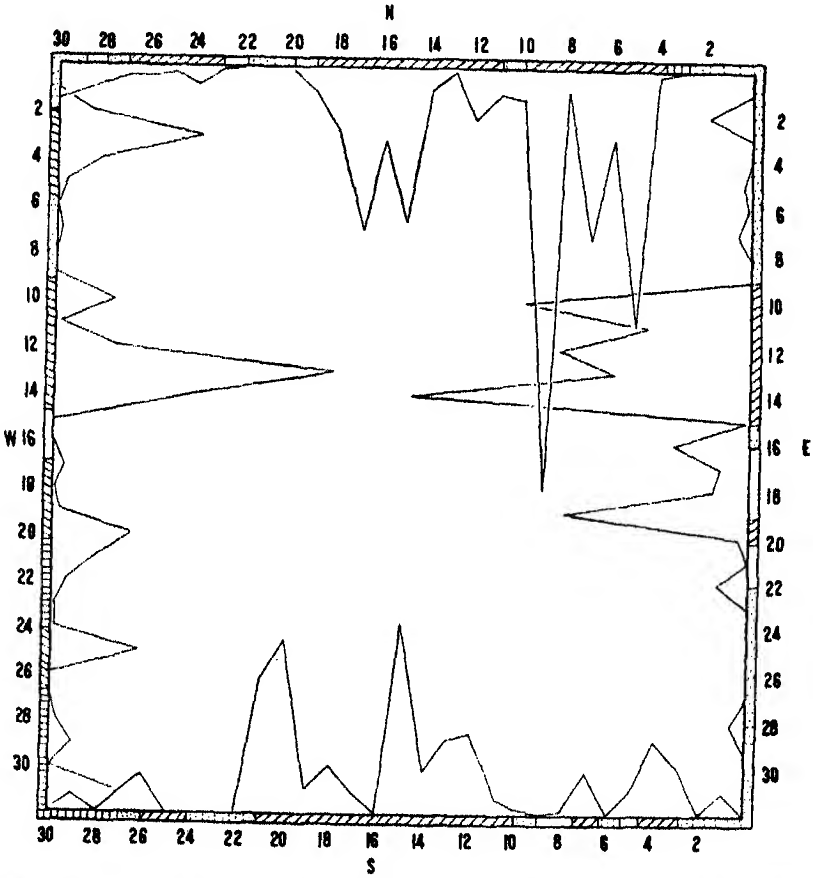
The Frequency of Stipa in Relation to Soil Type.

The distribution of *Stipa nitida* in relation to soil type is characteristic. This species is essentially a plant of sand and sandy-loam soils. This point is brought out clearly in Text-fig. 2, which is a chart showing the soil types around the fence of the Reserve, and the frequencies of *Stipa* plants in relation to these types. The numbers refer to the observation posts. The actual numbers of plants present per square metre at each post are indicated. These figures represent the frequencies in August, 1930, following the rains of December, 1929. The correlation existing between number of plants and the sandy soil is obvious from the figure.

Analyses of our data show that seedlings frequently are found on bare loam and on bare loam with travertine, but, although they may form small plants if a series of rains follow the rains causing germination, they rarely reach maturity and never form large tussocks. On the other hand the plants in the sandy or sandy-loam areas persist and form tussocks.

The same effect of soil type in relation to persistence of seedlings is illustrated in the quadrat chart in Text-fig. 3. This chart is from quadrat numbered 40 A, an area of 100 square metres. The soil is chiefly a hard loam with much travertine

rubble and normally carried a dwarf shrubland of *Kochia sedifolia* and *Atriplex stipitatum*, but was in a retrograde phase owing to heavy stocking prior to the enclosure of the Reserve. Small islands of more sandy or silt soils occur, however, and these are outlined in the figure. This chart shows the occurrence of seedlings and plants of *Stipa nitida* in August, 1928, before the incidence of the

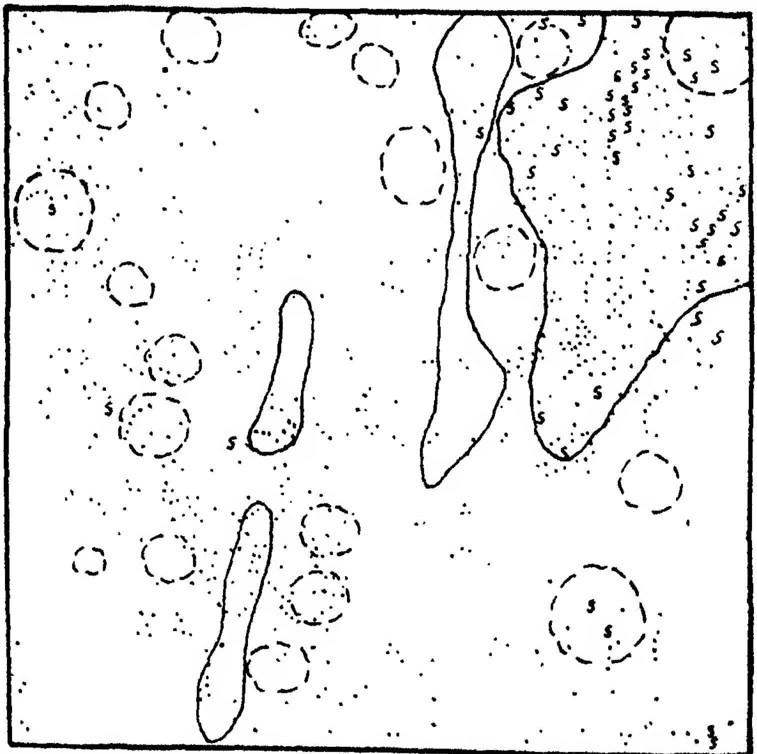


Text-fig. 2.—Plan showing the frequency of *Stipa nitida* in relation to soil type on 21/8/30. The plan represents the fences of the Reserve with the observation posts numbered. The soil types are indicated as follows: diagonal hatching, sand; vertical hatching, silt; blank, hard loam; dotted, hard loam with limestone rubble. The points represent actual numbers of plants.

drought of 1929; the mature plants are restricted to the sand or silt soils. The chart for this quadrat in March, 1930, after the drought period, showed that the *Stipa* plants were dead and had disappeared from the quadrat with the exception of tussocks remaining on the sandy islands. At this time living seedlings were present following the rains at the end of December, 1929, and were restricted to the sandy-loam areas in which the old tussocks remained.

The Importance of Litter.

The occurrence of the living *Stipa* seedlings around the old tussocks on the sandier soil, brings into prominence the importance of litter in relation to the occurrence of *Stipa* plants. There is a twofold significance in the occurrence of litter and of dead stumps of shrubs or of the living shrubs themselves. In the first place, the litter and the bases of the shrubs act as nuclei around which sand collects. It must be remembered that in arid Australia strong winds and dust-



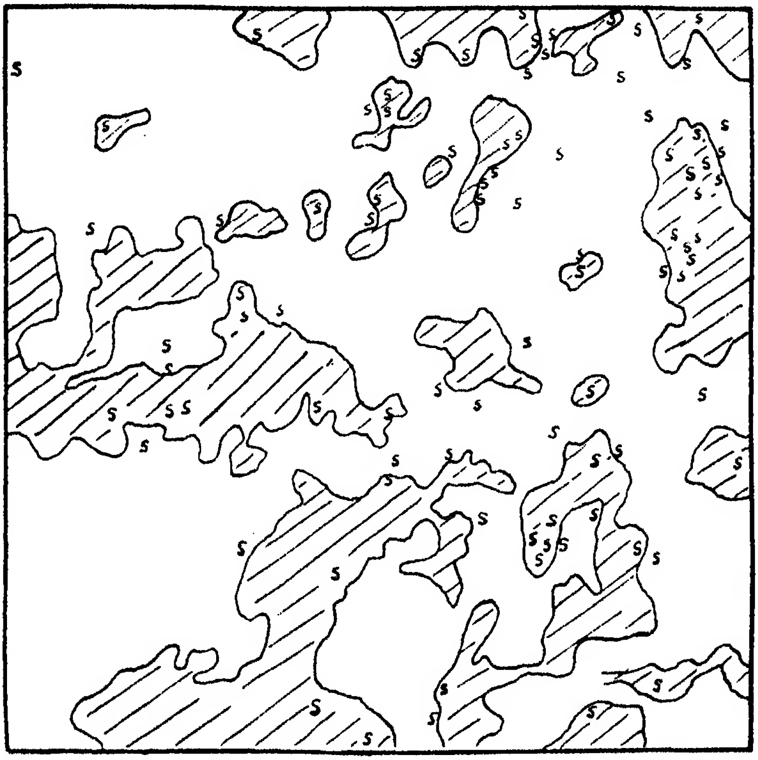
Text-fig. 3.—Quadrat chart of 40A, 30/8/28 (scale 1/100), showing relation of *Stipa* plants to soil type. A dot indicates small *Stipa* plants or seedlings, S indicates a large fruiting plant. The areas outlined with a full line have a layer of sand or silt on the surface. Areas outlined with a broken line are mounds of sand under blue-bushes. The rest of the area consists of a hard loam with travertine limestone nodules.

storms are of frequent occurrence, especially during the summer. Small accumulations of sand, and also the higher sandhills of arid Australia, invariably show better water relations than do the barer soils, for not only do they act (in the case of sandhills) as reservoirs of water but a sand covering forms an efficient mulch which prevents evaporation from the hard loam soils.

In the second place, litter and the shrubs tend to collect the fruits of *Stipa*, the awns becoming entangled in the litter. During heavy fruiting a veritable felt of tangled awns forms on the surface of the soil in and between objects that arrest the fruits.

The charts shown in Text-figs. 4 and 5 represent two observations on quadrat numbered 30; and show clearly the above-mentioned effects. This quadrat has an area 100 square metres and is situated at the junction of an occasionally flooded silt flat with slightly higher sandy ground. The dividing line between the two soil types lies approximately on a line drawn from the top left-hand corner of the quadrat to the bottom right-hand corner; the sandy soil lying to the right of the dividing line.

In Text-fig. 4 are shown the *Stipa* plants occurring on the quadrat following the rains of September, 1926. At this time of the year the ground was covered with much litter of *Bassia patenticuspis*, one of the pioneer Chenopodiaceous plants

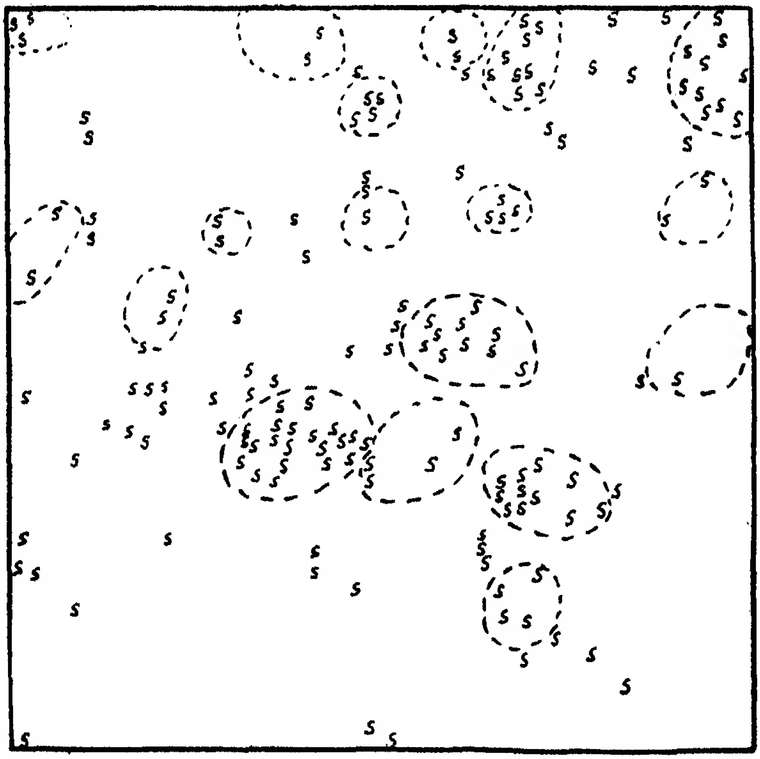


Text-fig. 4.—Quadrat chart of 30, 2/3/27 (scale 1/100), showing relation of *Stipa* plants to litter. S indicates *Stipa* plant. The area covered with litter of *Bassia patenticuspis* is outlined and shaded.

of bare areas. The plants of *Stipa* are practically confined to the area covered with litter. Text-fig. 5, on the other hand, shows the distribution of *Stipa* in May, 1928, following the rains of February of that year. By this time the litter of *Bassia patenticuspis* had disappeared and the importance of dead stumps and woody litter around which sand has become concentrated is clearly shown.

Stipa nitida occurs throughout the dwarf shrublands of *Atriplex* and *Kochia* which form the climax formation in arid Australia on certain hard loam soils with

travertine limestone. The *Stipa* here is always found following summer rains in the sandy mounds around the bases of the shrubs. It is, therefore, in its adult form a member of the climax formation on the plains as well as a normal constituent of the sandhill-scrub community which is an edaphic co-climax of the Chenopodiaceous shrublands.

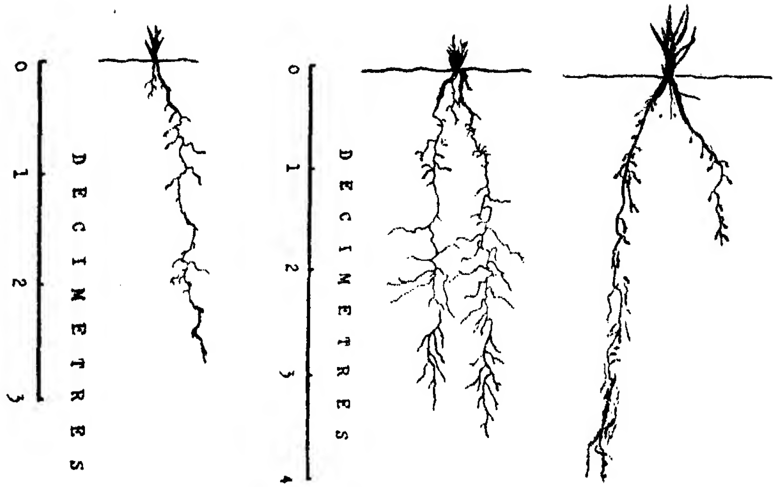


Text-fig. 5.—Quadrat chart of 30, 25/5/28 (scale 1/100), showing relation of *Stipa* plants to mounds of sand underneath bushes of *Kochia sedifolia* or around the dead stumps of that plant. S indicates *Stipa* plant. The area occupied by the mounds is outlined by a dotted line.

The Root-Systems of Stipa nitida in relation to soil type.

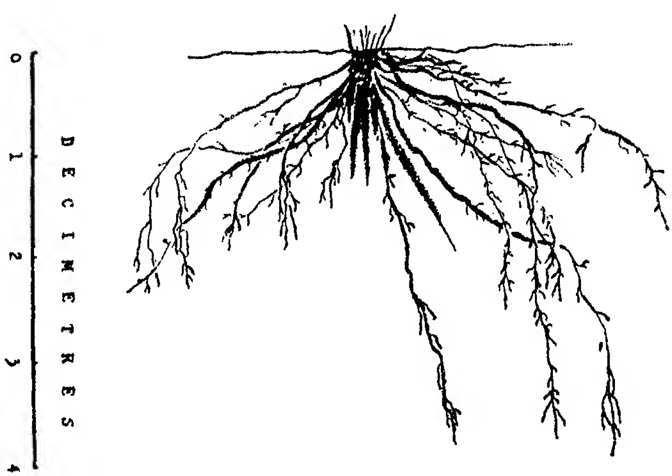
The strong development of *Stipa nitida* on sandy soils and its failure to persist in the hard loam soils with travertine rubble becomes quite clear when the root systems of the plants are compared.

Text-fig. 6 shows the root systems of seedlings and young plants in sandy soil. Following germination, the primary root descends quickly to a depth of 30–40 centimetres. This takes place when the plant has only 3–5 leaves, and the height of the plant above ground is 3–5 centimetres. The system of the adult plant is illustrated in Text-fig. 7. The whole is made up of a superficial system with copious root-hair development which enables the plant to utilize the light falls of rain so characteristic of arid Australia, and a more diffuse deep-seated root system



a *b* *c*

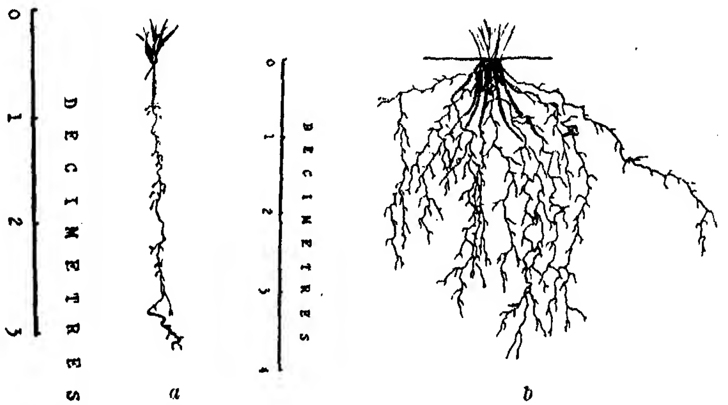
Text-fig. 6.—Development of root systems in *Stipa nitida*. The systems illustrate progressive stages of development in sandy soil. The first chart (*a*) is that of a seedling 4 cm. high, with five leaves; (*b*) is from a seedling 5 cm. high and (*c*) from a young plant 10 cm. high commencing to tiller. The very early establishment of the primary root to a depth of 30-40 cm. can be seen, and also the establishment of the two absorptive zones, the one superficial and the other more deep seated. T.B.P. *del.*



Text-fig. 7.—Root system of adult tussock of *Stipa nitida* growing in sandy soil. The diffuse nature of the lower roots with root hairs tapping the lower water supplies and the marked development of the superficial system are here illustrated. T.B.P. *del.*

which taps the underground water reserves. Root hairs are developed on these deeper roots at a depth of 20–40 centimetres.

In the hard loam soils with limestone rubble the root system is different. It will be recalled that a hard crust of travertine limestone usually occurs in this soil at a depth of about 30 cm. and that the soil is hard and dry. In this soil seedlings of *Stipa nitida* develop in a similar fashion to those in sandy soil by sending a primary root to a considerable depth (Text-fig. 8*a*). Larger plants have a different root system however. The superficial system is developed as



Text-fig. 8.—Root systems of *Stipa nitida* growing in hard loamy soil with much travertine limestone rubble. The seedling develops as in the sandy soil, but the different character of the root system of the adult plant, when compared with those growing in sand, is apparent. The superficial system develops as usual, but instead of the diffuse system seen in sand, a much branched system is formed with no absorptive hairs. T.B.P. *del.*

in sandy soils, but the deeper system is less effective. Instead of a diffuse system, the roots branch frequently and occupy a considerable portion of the soil, but root hairs are not developed on the deeper roots down to a depth of about 40 cm. when they reach the travertine crust. The root system of an adult plant in this soil type is shown in Text-fig. 8*b*. It follows that, after rains, *Stipa* plants can establish themselves on the hard loam soils; but when the soil dries out, as occurs rapidly on the saltbush plains, the deeper roots are not in contact with the water reserves of the soil and death of the plant follows.

VI. Biotic Factors.

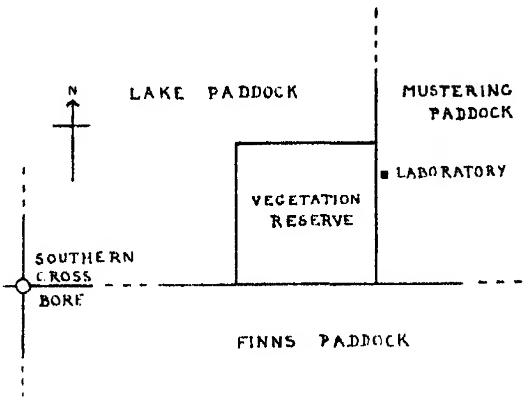
Description of the Biota.

Arid Australia, although of great extent, does not carry a large sheep population owing to the sparseness of the ground covering. The average carrying capacity of the country in which our investigations were carried out is approximately 40 sheep to the square mile, *i.e.*, one sheep to 16 acres. The herbage and grasses form the main forage, but a certain amount of browsing of the shrubby perennials always occurs, and in particular, saltbush (*Atriplex vesicarium*) palatable on account of its high salt content (Wood, 1925) is utilised.

Certain habits of sheep must be taken into account in a study of their effect upon the vegetation, and two characteristics stand out in particular. First, sheep

never travel very far from permanent water (dams or bores); the usual radius at which sheep feed around water is from 2 to 3 miles. Therefore in large paddocks (20 square miles and upwards) there occur areas of ungrazed vegetation. The second feature to be taken into consideration is the fact that sheep graze down the wind, particularly during the summer months. During these months the prevailing winds are from south to south-west so that the southern side of a paddock tends to become eaten out and trampled to a considerable degree, while conversely, the north side of the paddock shows very little effect of grazing. Thus there arise the "fence effects" frequently seen in arid Australia. On examining an east-west running fence between two paddocks, the ground in the paddock to the north of the fence may be almost bare, while on similar soil but to the south of the fence the ground may support a healthy growth of perennial vegetation (*cf.* Osborn, 1925, Pl. xxiv, fig. 2).

The relation of the Vegetation Reserve to the surrounding paddocks can be seen in Text-fig. 9. The area chosen for the Reserve was originally a sheep "camp" in the south-eastern corner of Lake Paddock. Sheep grazing on that paddock tended to work down wind and to congregate in the scrub growing in this



Text-fig. 9.—Diagram to show relation of the Koonamore Vegetation Reserve to the adjacent paddocks. Not to scale. Southern Cross Bore is about 4 miles to the west of the Reserve.

area. These were probably induced to remain there partly to gain shelter and also because they would smell water in some of the dams of Finn's Paddock across the fence. In this way any harmful effects of stocking became intensified and the area almost denuded of perennial vegetation, owing to the combined effects of grazing and trampling. This occurred in Lake Paddock for a distance of about two miles from the southern fence.

With the enclosure of the Reserve it will be seen that two new fences were made as arbitrary lines cutting off the enclosure from the surrounding denuded country in Lake Paddock. The north and west fences of the reserve crossed ground that at the time of enclosure was destitute of perennial Chenopodiaceous undershrubs. On either side of the two new fences the vegetation was in an equally degenerate state. Consequent upon the erection of the fences the portion lying outside the north fence of the Reserve became the new southern boundary of Lake

Paddock. This area, therefore, and to some extent that outside the new western fence of the Reserve, became subject to the severe stock-effects experienced in such a portion of a paddock. On the other hand, the area inside these new fences was protected from all grazing influences and the natural vegetation was free to regenerate there.

The two remaining fences of the Reserve were old boundary lines. That at the south had the northern portion of Finn's Paddock beyond it. This area then showed no harmful effects of grazing and had a good ground cover of Chenopodiaceous shrubs (Osborn, 1925, Pl. xxiv, figs. 1 and 2, shows photographs of this fence in 1925). The eastern fence of the Reserve divides it from Mustering Paddock, a small enclosure of some 16 square miles which for most of the year carries only a few ration sheep. Only at shearing time (usually August–September) is it heavily stocked by successive flocks of sheep remaining in it for a night or two. Along the boundaries of the Reserve this Paddock supports a dwarf shrubland of *Atriplex vesicarium* or *Kochia sedifolia.*

In addition to the grazing of sheep the effect of rabbits cannot be neglected. These vermin are present in numbers which fluctuate from season to season. The influence of their feeding has probably been of equal importance on all sides outside the Reserve. Inside the Reserve their numbers are kept as low as possible by systematic poisoning and stopping of the warrens. It has, however, not been practicable to exterminate them. Their effect inside the Reserve, except along the south fence, can be regarded as negligible so far as the present contribution is concerned. Occasional browsing by kangaroos, which are relatively rare, completes the list of animals which affect grazing. Kangaroos rarely remain in the Reserve for long owing to the presence of one of us who is constantly at the Research Station.

Under this section of the biotic factors we give practically the whole of our data from the metre counts along the various fences. These measure chiefly the influence of the biota, but the influence of drought conditions is also included and the disentangling of these two effects will be explained below.

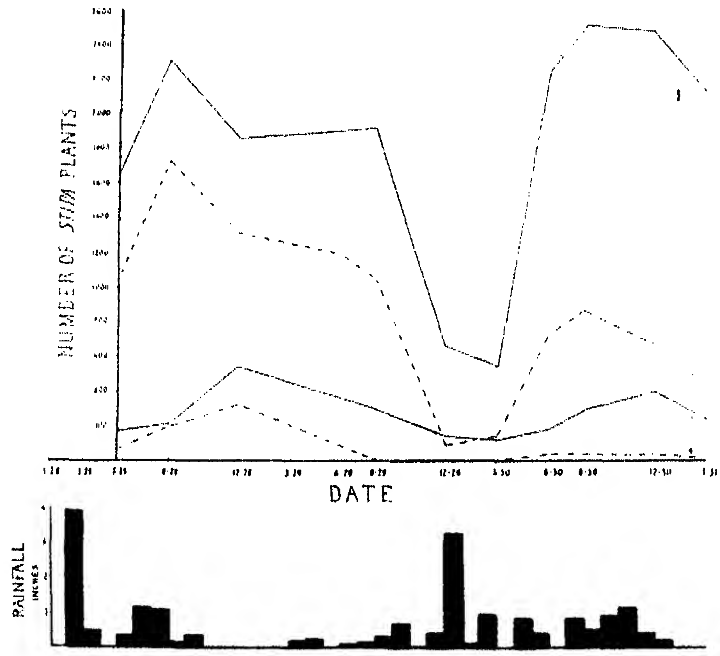
Frequencies of Stipa in relation to grazing.

In the upper two curves in Text-fig. 10 are graphed the total numbers of plants of *Stipa nitida* on our metre counts, inside and outside the four fences of the Reserve on different dates; in the lower two curves are shown the numbers of plants around the four fences which reached maturity, i.e. "tussocks".

It will be seen that the number of plants which germinated following the February rains of 1928 reached their maximum in August of that year. These plants reached maturity and were fruiting heavily in September, 1928. Inside the Reserve the total number of plants recorded remained at approximately the same level until August, 1929, although they were all dead by December, 1928, *i.e.*, soon after the beginning of the 15 months' drought. The violence of the climatic factors did not destroy these plants, however, until August, 1929, when, with the onset of summer, the strong wind erosion caused a gradual decrease in their numbers which reached a minimum in March, 1930. The drought broke with heavy rains at the end of December, 1929, and the numbers rose again in March, 1930. Inside the Reserve, therefore, potential fodder existed during the whole drought period.

Outside the Reserve, where the combined effects of drought and stocking were operative, the total number of plants gradually fell from December, 1928, to June, 1929, and from this time onward the numbers fell rapidly to zero in December,

1929. Over this period heavy stocking occurred along the northern and western fences (the sheep watering at Southern Cross bore to the south-west of the Reserve) and the consequent trampling aided the rapid wind erosion. The differences in the condition of the ground inside and outside the Reserve fences can be judged from the photographs in Pl. xviii, figs. 3 and 4. The photographs were taken from the same observation post on the north fence, and the denuded



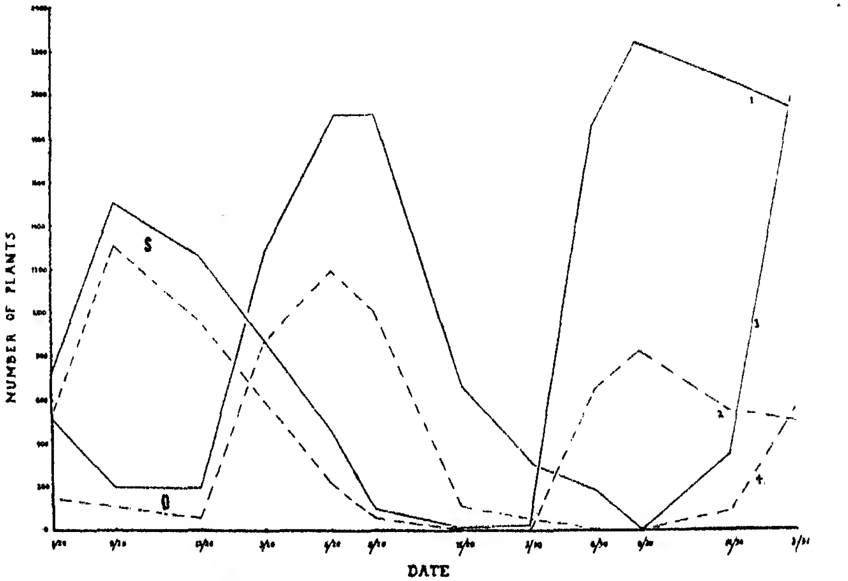
Text-fig. 10.—Curves showing total numbers of *Stipa* plants inside and outside the four reserve fences at different dates; and also numbers of large plants (tussocks). The monthly rainfall is also graphed. 1. Total *Stipa* plants inside the Reserve fences counted in the experiment; 2. Total *Stipa* plants outside the Reserve fences; 3. Total number of tussocks inside the Reserve fences; 4. Total number of tussocks outside the Reserve fences.

and trampled nature of the soil together with the large amounts of dung are evidence of the heavy stocking outside the Reserve. Inside the fence is a typical area of dry *Stipa* tussocks.

With the rain of February, 1930, the drought broke and a "normal cycle" to March, 1931, followed.

The relation of the "normal cycle" to the "drought cycle" becomes clearer in the curves of Text-fig. 11, in which are shown the numbers of small plants and seedlings, and the number of dead plants both inside and outside the Reserve fences on different dates. Two normal cycles are shown, the first from March, 1928, to March, 1929, all the plants being dead on the latter date; and the second normal cycle from March, 1930, to March, 1931. The drought cycle from March, 1929, to March, 1930, shows the gradual disappearance of the dead plants.

For the purposes of evaluating the effects of enclosure we have utilized "index numbers" which are expressed graphically for the total numbers of plants in Text-fig. 12. The "inside index number" is the percentage of *Stipa* plants inside the Reserve to the total number of plants inside and outside as recorded by our method of counting. The "outside index number" is the converse of this: the percentage of plants outside the Reserve to the total number of plants.

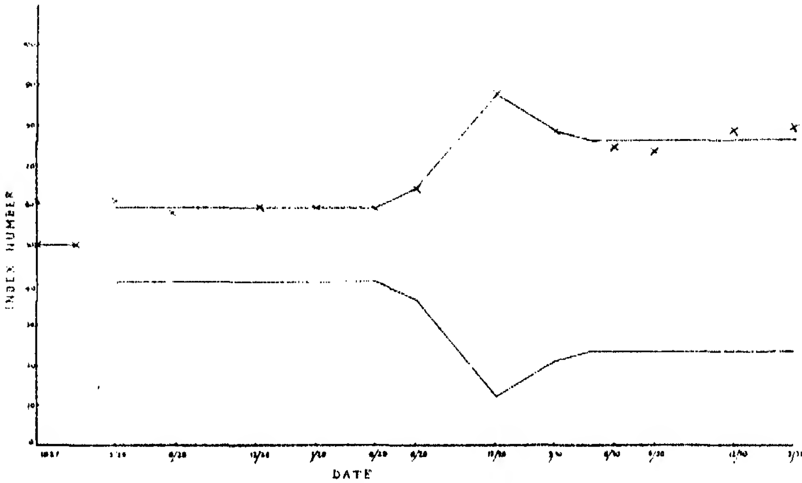


Text-fig. 11.—Curves showing (S) numbers of small plants and seedlings and (D) numbers of dead plants, around reserve fences during the period of investigation. (1) Number of small plants and seedlings inside the Reserve fences; (2) Number of small plants and seedlings outside the Reserve fences; (3) Number of dead plants inside the Reserve fences; (4) Number of dead plants outside the Reserve fences.

Counts were first made in March, 1927, about 18 months after the enclosure of the Reserve. The index number is here 50, indicating that equal numbers of plants occurred both inside and outside the Reserve. Since May, 1928, counts have been made every three months. The normal cycle over the season March, 1928, to March, 1929, showed that enclosure and consequent protection from grazing had raised the value of the datum index line inside the Reserve to 60. This value remained constant until June, 1929, when drought effects began to be appreciable. The constancy of the index number over this period is remarkable and serves as a check on the accuracy of our methods of counting. The constancy of the index number means that during a normal cycle the combined effects of the grazing and climatic factors do not disturb the balance between the plants outside and inside the fences of the enclosure; although plants outside the fences may be grazed they do not disappear and may shoot again and act as potential centres for seed dispersal.

With the onset of the drought the inside index numbers rose rapidly reaching the value of 88 in December, 1929, and indicating that practically all the plants

outside the Reserve had disappeared. During this period the combined influences of drought and grazing were affecting the plants outside the Reserve.



Text-fig. 12.—Graph showing the index numbers of total number of *Stipa* plants around Reserve fences. Upper curve, inside index number; lower curve, outside index number.

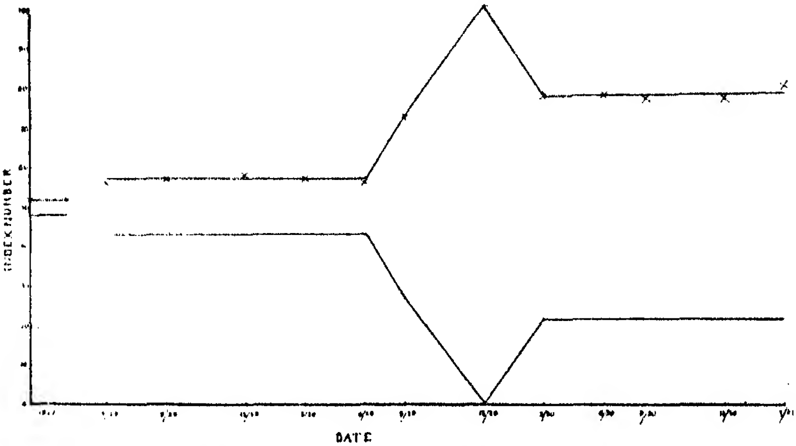
After the breaking of the drought with the rains of February, 1930, a new datum line has been established for the inside index number with a value of 74. Over this normal cycle from March, 1930, to March, 1931, again the balance has been maintained but owing to the influence of the preceding drought combined with stocking, the percentage of plants occurring outside the area has been very appreciably reduced. It may be said that, should another series of drought cycles now intervene during which stocking occurred, the amount of spear grass growing in the stocked areas would tend to diminish to a still greater extent.

As things stand at present, over the period of our investigations the amount of spear grass in the paddocks around the Reserve has been reduced to one-half from May, 1927, to June, 1930. That this disappearance of the grass is due primarily to sheep grazing and not directly to the drought is made clearer when the cases of the individual fences are considered.

During the period of our investigations the north and west fences outside the reserve (in Lake Paddock, Text-fig. 9) have been stocked almost continuously. The south fence outside the reserve (in Finn's Paddock) was stocked heavily up to December, 1928, but from that time to the close of our investigation, and including the drought period it has been stocked only very lightly, there being no evidence of trampling or dung along the Reserve fence.

The west and north fences show a similar type of curve for the index numbers to that of the index number of the total fences. The curve for the index numbers of the west fence is given in Text-fig. 13. In 1927 the inside index number was 52. This rose to 57 during the normal cycle of 1928–1929 and reached 100 at the peak of the drought period in December, 1929, when there were no plants present outside the fence. In the following normal cycle, the inside index number reached a new

datum line at 78. Outside this fence the number of *Stipa* plants has been more than halved during the period May, 1927, to March, 1930.



Text-fig. 13.—Graph showing the index numbers of plants along the west fence of the Reserve. Upper curve, inside index numbers; lower curve, outside index numbers.

The index numbers for the north fence have not been expressed graphically, but they are essentially similar in character as can be seen from the following table.

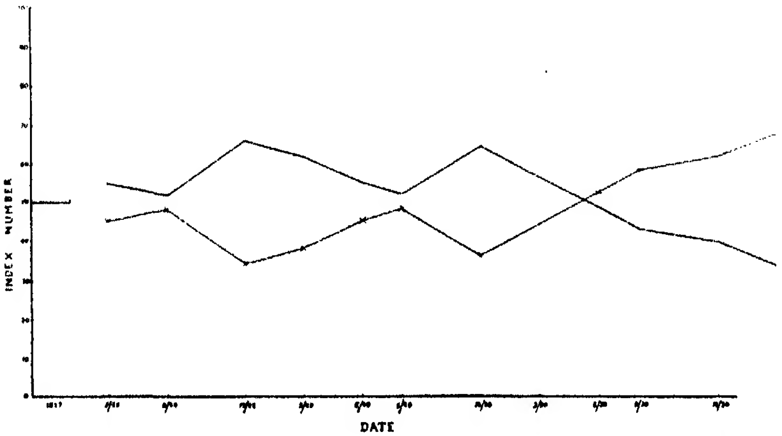
Table showing value of the inside index number along the north fence at different dates.

Date.	*Index Number.*	*Date.*	*Index Number.*
March, 1927	45	December, 1929	78
May, 1928	58	March, 1930	82
August, 1928	58	June, 1930	73
December, 1928	58	August, 1930	74
March, 1929	57	December, 1930	78
June, 1929	57	March, 1931	70
August, 1929	57	June, 1931	83+

In contrast to these two fences is the south fence (Text-fig. 14). It has been mentioned already that the paddock (Finn's) outside this fence was not stocked during the drought period.

Along the south fence, when the enclosure was first made, there were practically no plants inside the Reserve, since this was the most eaten-out section of the paddock. By May, 1928, there were approximately equal numbers of *Stipa* plants inside and outside the Reserve (Text-fig. 14). At this time the inside index number was 45 and at the close of the first normal cycle (August, 1928) it was 48. During the drought the maximum value for this index number rose only to 49 and at the onset of the second "normal cycle" (March, 1930) it was again 48. Since this date it has shown a slight but steady rise during the 1930 "normal cycle". The index numbers for this fence, therefore, have remained approximately constant over the whole of the period investigated, and the balance of the plants, inside and outside, has not been very appreciably disturbed. The fluctuations of

the curve are possibly due to rabbits, for our field notes show that many of the grasses both inside and outside this fence have been grazed by them, particularly in 1928 and again in 1930. The present trend of the curve is slightly favourable to the Reserve, the inside index number being now in the neighbourhood of 60. This is probably only to be expected after five years' enclosure.



Text-fig. 14.—Graph showing index numbers along south fence of the Reserve. Curve marked with crosses, inside index numbers; other curve, outside index numbers.

The lack of marked change along this fence, which has been unstocked outside the Reserve, proves conclusively that during a drought cycle climatic factors alone do not disturb the balance between the plants; but that when excessive trampling and grazing aggravate the adverse action of the climatic factors (as, for instance, along the north and west fences), the grass is virtually exterminated.

The data for the total numbers of plants around the fence bear out the conclusions drawn from the index numbers. The following table shows the actual numbers of *Stipa* plants recorded by our metre counts inside and outside the Reserve fences in August, 1928, and August, 1930, that is, before and after the drought period.

	Inside.				Outside.			
Fence:	N.	S.	E.	W.	N.	S.	E.	W.
August, 1928	740	385	560	483	532	414	77	483
August, 1930	800	506	706	520	270	357	76	160

The reduction in the number of plants along the north and west fences outside the Reserve is so striking that further comment is unnecessary.

The number of *Stipa* plants along the east fence outside the Reserve on the hard loamy soil with limestone nodules in Mustering Paddock has remained at a constant low level. The larger numbers of plants along this fence inside the Reserve are due to the presence of several sandhills as indicated in Text-fig. 1.

Even more striking evidence of the damage wrought by stock and rabbits can be seen from a comparison of the numbers of large plants, tufts and tussocks, inside and outside a heavily grazed fence. For this comparison we have selected

the north fence. The absolute numbers of large plants by our method of sampling inside the Reserve and outside and the inside index number calculated from them are shown in the following table:

Table showing actual numbers of large *Stipa* plants inside and outside the north fence together with the inside index numbers.

Date.	Large Plants.		Index Number.
	Inside.	Outside.	Inside.
May, 1928	18	9	66
August, 1928	146	84	63
December, 1928	171	64	73
March, 1929	—	—	—
June, 1929	—	—	—
August, 1929	74	0	100
December, 1929	30	0	100
March, 1930	42	0	100
June, 1930	85	25	73
August, 1930	62	32	66
December, 1930	130	18	88
March, 1931	78	62	56
June, 1931	221	8	96

In this table the larger plants only have been considered because they are the plants of chief fodder value, and also the potential sources of seed. At the present time they are practically exterminated along this fence outside the Reserve. Yet, as can be seen from the rainfall table, the 1930–31 season has been a "good" one, although there have been no soaking rains to produce a general germination of *Stipa* seeds. In June, 1931, there were many herbage plants other than *Stipa* outside the fence, but grass was conspicuously absent. That grazing by stock and rabbits is responsible can be seen from certain small rabbit and sheep proof enclosures erected in the paddock near to the fence. One such, near observation post 10, had, in June, 1931, 8 tufts of *Stipa* within it on an area of about 1 square metre. This is as many as were recorded by our samples along the whole length of the fence outside the Reserve.

VII. Stipa nitida in Relation to the Other Herbage.

There remains to be considered the other herbage associated with *Stipa nitida*. The chief plants are *Bassia patenticuspis* (Bindyi), *Zygophyllum ovatum* (squash) and *Tetragonia eremaea* (spinach). Of these plants *Bassia patenticuspis* and *Tetragonia eremaea* reach their maxima coincidently with *Stipa nitida*. *Zygophyllum ovatum* appears before the other plants, immediately following early summer rains. *Zygophyllum ammophilum* appears later in March to June; as the name implies it is almost restricted to sandy soils. With the early summer rains, *Salsola Kali* (buckbush) and *Chenopodium cristatum* also become plentiful.

The chief interest, as far as our records of the herbage other than *Stipa* show, is the persistence of *Bassia patenticuspis* throughout the whole of the drought period. The drought resistance of the Chenopodiaceous plants is remarkable and is probably due in no small measure to their capacity for water absorption through their leaves (Wood, 1925). The success of *Bassia patenticuspis* as a pioneer colonizer of bare areas is also reflected in this drought resistance.

There appears to be relatively little loss of *Stipa* plants through competition with other plants, probably owing to the early development of the deep root system. In dense masses of litter under occasional trees, and particularly among the fallen phyllodes of *Acacia Burkittii* in the sandhills, seedlings disappear. In favourable situations following rain enormous numbers of seedlings, chiefly of small ephemeral plants, appear. Two examples from our metre counts illustrate this point:

(1) 500 *Tetragonia eremaea*, 119 *Stipa nitida*, 6 *Zygophyllum ammophilum*, 2 *Erodium cygnorum*, 5 *Calotis hispidula*, 5 *Helipterum moschatum*, 5 *Calandrinia volubilis*.

(2) 10 *Stipa nitida*, 60 *Tetragonia eremaea*, 3 *Brachycome pachyptera*, 4 *Sonchus oleracea*, 3 *Erodium cygnorum*, 1 *Erodium cicutarium*, 2 *Euphorbia Drummondii*, 1 *Lavatera plebeja*, 8 *Bassia patenticuspis*, 2 *Helipterum moschatum*, 2 *Trisetum pumilo*, 1 *Daucus glochidiatus*, 3 *Calotis hispidula*, 5 *Geococcus pusillus*.

Such dense aggregations of plants as these are unusual, however, and *Stipa nitida* is generally a member of an open community on sand or sandy loam.

VIII. Summary and Conclusions.

1. The investigations described in this paper were carried out at the Koonamore Vegetation Reserve in the north-eastern district of South Australia. They form part of a more extensive programme having as its object the study of the arid flora of this area. The Reserve forms the Arid Flora Research Station of the University of Adelaide. The work described herein has been aided, in part, by a grant from the Commonwealth Council for Scientific and Industrial Research.

2. *Stipa nitida* S. & H. is the most important fodder grass in the north-east of South Australia. It is a species demanding very definite requirements of its habitat. Plants only reach full maturity, forming large tussocks, on sandy or sandy-loam soils. On soil of this type *Stipa nitida* may form a constituent of any of the major communities in arid South Australia.

3. A correlation exists between the soil type and the root system developed. This consists of a fairly compact surface-rooting portion and a more diffuse deeper-rooting part extending to a depth of over 40 cm. By means of this double root-system the plant is able to utilize light falls of rain that wet the surface soil only, in addition to tapping the deeper water reserves of the soil.

4. The nature of the seed-bed is of importance. The ideal seed-bed is of sand. Litter, consisting of the dead remains of other herbage, plays an important part in entangling the fruits of the grass. Seeds will germinate on hard loamy soil but fail to reach maturity there.

5. The percentage germination of the seed is low. Laboratory experiments have shown that the soil must be saturated and that light is a factor.

6. Observations show that germination in the field is best following late summer rains. The active growing season extends throughout the autumn and winter months. Flowering occurs towards the end of the cold season and spring months, and the fruits are shed in the early summer months.

7. The influence of grazing upon the grass has been studied by means of an extensive quadrat system both inside the Reserve and also in the adjacent paddocks. It has been possible in this way to make a comparison between the

entirely protected plants of the Reserve and those outside it which have been subjected to different intensities of grazing.

8. By utilizing "index numbers" which express the ratio between the plant growing inside or outside the Reserve and the total number of plants, it has been shown that the balance between the plants inside and outside the fences has been seriously affected by the combined effects of grazing and drought during the period of our investigation.

9. Considerations of the individual fences have shown that the intense drought conditions which prevailed during 15 months of our investigation have not been the only cause of the reduction in number of plants and failure of the grass to regenerate outside the Reserve.

10. Large numbers of sheep which have been compelled of necessity to water at definite bores and dams in the vicinity have seriously diminished the numbers of plants without the Reserve. This has been effected in two ways—(i) by obliterating, through grazing and trampling, plants that would serve as potential seed centres ("nurse" plants); (ii) the soil, following the removal of most of the plant cover, has assumed a labile state in which it is easily moved by wind or heavy rains. When this occurs a hard loamy soil with nodules of travertine limestone is exposed and on this soil type *Stipa nitida* fails to establish itself.

11. This investigation shows that only by careful control of grazing during drought periods can the population of *Stipa* plants be maintained. It also shows that on an area that shows degeneration of the plant cover, as *e.g.* the Reserve itself prior to enclosure, "spelling" (leaving the area ungrazed) for one or two years very materially benefits the *Stipa* population.

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EXPLANATION OF PLATE XVIII.

1.—Vigorous community of *Stipa nitida* in light sandy soil on the Reserve, showing tussock habit and open nature of the community. Rainfall, 365 points in February, 1928. Photographed 25.8.28.

2.—Tussocks of *Stipa nitida*. The grazed plants near the pocket knife grew prior to the fencing of the Reserve (length of handle, 3½ inches).

3.—Photograph taken from observation post No. 17, along north fence inside the Reserve, showing good growth of tussocks of *Stipa nitida* on sandy soil, June, 1929. These are dead at this period.

4.—Photograph taken from same observation post, No. 17, along north fence outside the Reserve in Lake Paddock. Note complete absence of *Stipa nitida*, although the soil type is the same. The trampled nature of the soil and the large amounts of dung are evidences of the heavy stocking. June, 1929.

REVISION OF AUSTRALIAN LEPIDOPTERA. SUPPLEMENTARY.

By A. Jefferis Turner, M.D., F.E.S.

[Read 30th September, 1931.]

This instalment consists of corrections and additions to the families previously treated in this revision, together with some new species belonging to groups that I have revised at earlier dates.

Family Lymantriadae.

Icta tanaopis Turn.

♀. Pale reddish-ochreous. Antennae short; very shortly bipectinate. Wings rudimentary. Tibial spurs short; posterior tibiae without middle spurs.

Mr. W. B. Barnard took this semi-apterous female together with two male examples at Cape York, North Queensland, in April and May.

Porthesia aliena Butl.

Hitherto known only by the British Museum type from the Peak Downs, Queensland. I rediscovered this species at Charters Towers in June, 1927, and it probably has an extensive inland distribution. My examples were three males expanding 30–32 mm. The distinguishing feature of this species is the coloration of the abdomen, which varies somewhat. It is ochreous or orange-ochreous, and sometimes the bases of the segments are fuscous on the dorsum. The underside of the hindwings is not ochreous in my examples, but the underside of the forewings has a fuscous-brown costal line from base variably developed.

Porthesia melanorrhanta, n. sp.

μελανοῤῥαντος, sprinkled with black.

♀. 33 mm. Head, thorax and palpi white. Antennae white; pectinations in female 5. Abdomen grey-whitish; tuft in female large, ochreous. Legs white; anterior pair ochreous-tinged. Forewings oval-triangular, costa strongly arched, apex rounded, termen slightly rounded, strongly oblique; 10 absent; white very sparsely irrorated with large blackish scales; cilia white. Hindwings with termen rounded; white; cilia white.

North Queensland: Palm Islands in May; one specimen received from Mr. G. H. Hardy. We await with interest the discovery of the male of this very distinct species.

Acyphas pelodes.

Euproctis pelodes Low., *Trans. Roy. Soc. S. Aust.*, 1893, p. 150.—*Orgyia retinopepla* Low., *ibid.*, 1905, p. 176.

♂. 24–28 mm. Head, palpi, thorax, abdomen, and legs brown or whitish-brown. Antennae brown or whitish-brown; pectinations in male 8 to 10. Forewings triangular, costa straight to near apex, apex rounded, termen obliquely rounded;

uniformly brown, or suffused with whitish-brown leaving a darker basal patch, an outwardly curved transverse line at one-fourth, a subcostal median discal dot, and a sinuate line from three-fourths costa to two-thirds dorsum; an interrupted whitish sinuate transverse line just beyond this; cilia brown. Hindwings with termen rounded; brown; cilia brown. Underside brown.

New South Wales: Broken Hill in October; South Australia: Adelaide. Two specimens from the Lower Collection in the South Australian Museum. The latter is believed to be the type of *pelodes*, the former is the type of *retinopepla*. The differences between them are, I am convinced, merely varietal. My former conjectural identification of *pelodes* was very wide of the mark.

Acyphas aneliopa.

Orgyia aneliopa Low., *Trans. Roy. Soc. S. Aust.*, 1915, p. 478.

♂. 30 mm. Head and thorax fuscous-brown; face and palpi ochreous-brown. Antennae brownish; pectinations in male 12. Abdomen clothed in long ochreous hairs. Legs fuscous. Forewings triangular, costa nearly straight, apex round-pointed, termen gently rounded, oblique, fuscous-brown; an ill-defined fuscous discal mark beneath costa beyond middle; a suffused, fuscous, nearly straight line from costa before apex to dorsum before tornus; cilia fuscous. Hindwings with termen rounded; fuscous; cilia fuscous. Underside fuscous.

South Australia: Pinnaroo. Described from one example in the Lower Collection.

Habrophylla euryzona Low.

Euproctis pycnadelpha Low., *Trans. Roy. Soc. S. Aust.*, 1903, p. 28, is a slight aberration of this species. I have examined the type.

Euproctis epaxia Turn.

I took a much better example of this species at Kuranda last June, and can therefore give a better description.

♂. 20–26 mm. Head and palpi pale-orange. Antennae whitish-ochreous; pectinations in male 10–12. Thorax and abdomen orange. Legs whitish-ochreous; anterior and middle tibiae and tarsi with long orange hairs. Forewings oval-triangular, costa strongly arched, apex rounded, termen rounded, moderately oblique; orange-ochreous; costal margin and veins pale-ochreous; two broad transverse fasciae purple-fuscous or reddish-fuscous, densely irrorated with whitish; first subbasal, not reaching costa, defined posteriorly by a pale-ochreous line; second subterminal, indented anteriorly above middle, projecting posteriorly in middle and beneath costa, defined anteriorly by a pale-ochreous line; cilia pale-ochreous with an orange-ochreous median line. Hindwings with termen rounded; pale-ochreous; cilia pale-ochreous.

Euproctis emprepes, n. sp.

ἐμπρεπες, conspicuous.

♂. 25–33 mm. Head, palpi, thorax, abdomen, and legs pale-ochreous. Antennae pale-ochreous; pectinations in male 8. Forewings suboval, costa strongly arched, apex rounded, termen obliquely rounded; ochreous-yellow; a paler outwardly curved transverse line from one-third costa to one-third dorsum; a similar line from two-thirds costa to two-thirds dorsum, angled outwards in middle; first line preceded by a reddish-brown moderate fascia from dorsum extending half-way

towards costa; second line followed by a narrow, more or less interrupted, reddish-brown fascia, not reaching costal margin, strongly angled outwardly in middle; cilia ochreous-yellow. Hindwings with termen rounded; pale-ochreous; cilia pale-ochreous.

The fasciae are narrower than in *epaxia*, differently formed, and not irrorated with whitish.

North Queensland: Kuranda near Cairns in August; Herberton in April; Ravenshoe in December; four specimens (F. P. Dodd and W. B. Barnard).

EUPROCTIS OCHRONEURA, n. sp.

ὠχρονευρος, with pale nerves.

♂. 21 mm. Head and thorax pale-ochreous. Palpi 1, terminal joint minute; ochreous. Antennae pale-ochreous; antennal pectinations 10. Abdomen ochreous; tuft paler. Legs pale-ochreous. Forewings suboval, costa strongly arched, apex rounded, termen obliquely rounded; pale-ochreous with orange-ochreous markings; a subbasal line outwardly dentate; a suffused partial fascia from costa about one-fourth half-way across disc; a narrow fascia from costa before middle to two-fifths dorsum, wavy; a broader suffused fascia from three-fourths costa to three-fourths dorsum, traversed by pale streaks on veins, strongly outwardly curved; a subterminal fascia intersected by pale streaks on veins; cilia whitish-ochreous barred with orange-ochreous. Hindwings with termen rounded; 3 and 4 short-stalked, 5 approximated; orange-ochreous; cilia as forewings.

♀. 24 mm. Antennal pectinations 10. Wings paler, markings suffused and very indistinct.

There seems to be no difference in the antennal structure of the two sexes.

North Queensland: Cape York in October and November; two specimens taken by Mr. W. B. Barnard, who has the types.

Genus DURA.

In my revision the characters of this genus are correctly given, but in the key there is an error. *Dura* should fall under (9), 7 of forewing arising from well before 10, and then be separated by 11 connected with or closely approximated to 12.

DURA NIVEA.

Imaus niveus B-Bak., *Novitat. Zoolog.*, 1904, p. 409.

♂. 68 mm. Head white. Palpi white; external surface blackish. Antennal stalk white; pectinations in male 8, ochreous. Thorax, abdomen, and legs white; pectus white with a blackish spot behind each eye. Forewings triangular, costa strongly arched, apex rounded, termen moderately rounded, scarcely oblique; 11 connected with 12; uniformly white but with raised scales, which, when rightly illuminated, are seen to form an embossed pattern of the markings common in the genus, namely circular spots beneath costa at one-third and one-half; from the latter an incompletely defined series of spots to one-third dorsum, a sinuate line of spots from three-fourths costa to two-thirds dorsum, and a subterminal series of spots; a series of minute marginal fuscous dots between veins around apex and termen; cilia white. Hindwings subquadrate, termen with a prominent rounded angle on vein 3; white; cilia white. Underside white.

Mr. Bethune-Baker's description is very imperfect, but it can hardly refer to any other species.

North Queensland: Kuranda near Cairns; one specimen taken by Mr. A. P. Dodd. Also from New Guinea.

LAELIA FURVA, n. sp.

furvus, dark.

♂. 30–33 mm. Head orange-ochreous. Palpi 3; orange-ochreous. Antennae fuscous-grey; patagia orange-ochreous. Abdomen fuscous-grey. Legs grey; anterior pair orange-ochreous. Forewings triangular, costa nearly straight, apex rounded, termen nearly straight, not oblique, rounded beneath; fuscous-grey; cilia grey. Hindwings with termen rounded; fuscous-grey; cilia grey.

Perhaps this is only a local race of *L. obsoleta*.

North Queensland: Cape York in June; two specimens received from Mr. W. B. Barnard, who has the type.

Family ANTHELIDAE.

PTEROLOCERA ISOGAMA, n. sp.

ἰσογαμος, equally mated.

♂. 54–58 mm.; ♀. 52–64 mm. Head, palpi, thorax, abdomen, and legs fuscous-brown. Antennae in male fuscous, pectinations in male extremely long (16 to 20): in female brown with short (1½) fuscous pectinations. Forewings triangular, narrower than in *amplicornis*, costa in male sinuate, in female nearly straight, apex round-pointed, termen gently rounded, strongly oblique; uniform fuscous-brown; cilia brown. Hindwings with termen rounded; colour as forewings.

The male agrees structurally with *amplicornis*, but may be easily distinguished by the different shape of forewings—narrower, more elongate, termen much more oblique—and their uniform coloration. The female is very similar and fully winged, contrasting markedly with the completely apterous female of *amplicornis*.

Western Australia: Beverley, Quairaiding, and Cunderdin; four specimens.

Family BOMBYCIDAE.

COTANA AROA.

Nervicompressa aroa B-Bak., *Novit. Zoolog.*, 1904, p. 392.

♂. 38–40 mm. Head reddish-brown. Antennae dark fuscous; pectinations in male 4. Thorax ochreous-grey. Abdomen reddish-brown. Legs brown. Forewings triangular, costa straight to two-thirds, thence moderately arched, apex rounded, termen slightly rounded, not oblique; basal area sharply defined by a straight line from midcosta to before mid-dorsum, ochreous-whitish, containing a broadly suffused, outwardly curved, transverse, fuscous, subbasal line, followed by a thickly outlined fuscous ring; beyond median line a very broad pale fuscous suffusion, broader above middle; terminal area pale-grey, containing two more or less distinct, parallel, transverse, fuscous, crenulate lines, and a suffused subapical, terminal, fuscous blotch; cilia fuscous, towards termen pale-grey. Hindwings with termen strongly rounded; orange-ochreous; an oblique fuscous line from mid-dorsum towards but not reaching costa at one-third; two crenulate fuscous, subterminal lines; cilia fuscous, on dorsum orange-ochreous.

North Queensland: Cape York in November; five specimens received from Mr. W. B. Barnard. Also from New Guinea.

Family NOTODONTIDAE.

SYNTYPISTIS ARISEMNA, n. sp.

ἀρισεμνος, very stately.

♂. 65 mm.; ♀. 83–87 mm. Head with a sharp median crest of scales; greenish-grey; face brown-whitish above, brown beneath. Palpi 1, ascending; pale-brownish, posteriorly fuscous. Antennae grey; pectinations brown, in male 12, in female 6. Thorax crested posteriorly; greenish-grey mottled centrally with brownish. Abdomen grey. Legs brown-whitish. Forewings oval, costa strongly arched, apex rounded, termen very obliquely rounded; greenish-grey, in female more whitish in subbasal and terminal areas; three rather confused, dentate, fuscous lines near base, the last oblique to one-sixth dorsum; two strongly but irregularly dentate transverse fuscous lines at one-third, the first more strongly marked in female, between them some brownish suffusion; similar but less strongly dentate transverse lines at two-thirds, the second more strongly marked in female; no defined discal spot, but some brownish mottling in female; terminal area paler, and suffused with whitish posteriorly; a dentate line near termen, the dentations being connected along veins with terminal edge; cilia pale brownish mottled with greenish-grey and pale fuscous. Hindwings with termen rounded; grey; cilia grey, apices whitish.

North Queensland: Cape York in April; three specimens received from Mr. W. B. Barnard, who has the type.

Pheraspis epiocosma, n. sp.

ἠπιοκοσμος, softly adorned.

♂. 45–47 mm. Head and thorax ochreous-brown-whitish. Palpi 1, ascending; ochreous-whitish irrorated with dark fuscous, posterior surface dark fuscous. Antennae fuscous becoming ochreous-whitish towards base; in male shortly ciliated (½). Abdomen ochreous-brown-whitish. Legs pale ochreous; tarsi annulated with fuscous. Forewings elongate-oval, costa straight to middle, thence rounded, termen very obliquely rounded; pale ochreous-grey, brownish-tinged, with some fuscous irroration towards costa and on veins; markings dark fuscous; a fine line from midcosta towards tornus abruptly curved inwards in mid-disc, thence twice sinuate to one-third dorsum; just beyond this are traces of a discal spot; two fine parallel lines from costa at five-eighths and three-fourths, at first outwardly oblique, then bent and finely dentate to dorsum at two-thirds and five-sixths, anastomosing above dorsum; three fine parallel black streaks beneath apical fourth of costa, the uppermost fine and short, the middle one wedge-shaped with base anterior, the lowest longer and somewhat anterior; a subterminal series of blackish dots; cilia whitish mixed and obscurely barred with brown. Hindwings with termen gently rounded; pale ochreous; a suffused fuscous terminal line; a blackish spot edged marginally with whitish at tornus; cilia pale ochreous, on termen mixed with fuscous.

North Queensland: Cape York in October; two specimens received from Mr. W. B. Barnard, who has the type.

Destolmia atalopa, n. sp.

ἀταλωπος, delicate.

♂. 42 mm. Head whitish; sometimes a transverse line on face. Palpi 1, porrect; whitish, upper surface towards base fuscous. Antennae whitish-ochreous; in male with long pectinations (8) nearly to apex. Thorax whitish; anterior and posterior crests ochreous-tinged anteriorly. Abdomen grey-whitish. Legs whitish; anterior and middle tarsi annulated with fuscous. Forewings elongate-oval, costa gently arched, apex rounded, termen obliquely rounded; whitish with some fine

fuscous irroration, partly ochreous-tinged in disc; veins finely irrorated with fuscous; two short longitudinal blackish streaks in posterior part of cell, and two beneath cell towards base; three dark fuscous dots followed by white dots on veins at three-fourths; sometimes an interrupted, oblique, short, dark fuscous streak from apex; cilia dark grey; apices and slender bars on veins whitish. Hindwings with termen gently rounded; grey; cilia as forewings.

Western Australia: Denmark in March; two specimens received from Mr. W. B. Barnard, who has the type.

Antimima corystes, n. sp.

κορυστης, wearing a helmet.

♀. 40 mm. Head grey; face with a short, conical, obtuse, anterior process, excavated at apex. Palpi moderate, obliquely ascending; dark fuscous mixed with white anteriorly. Antennae grey, darker towards apex. Thorax dark grey with some whitish hairs. Abdomen grey, posteriorly mixed with whitish. Legs fuscous mixed with whitish; posterior pair mostly whitish. Forewings elongate-triangular, costa slightly arched, apex round-pointed, termen moderately rounded, moderately oblique; grey with some whitish irroration; markings blackish; a short suffused line from costa near base to middle of disc; a fine crenulate line from two-fifths costa to two-thirds dorsum; orbicular circular, slenderly outlined, containing a tuft of raised scales, immediately beyond this line; reniform similar but transversely oval, at three-fifths, suffusedly connected with costa; a strongly sinuate, slightly dentate line from four-fifths costa to four-fifths dorsum, succeeded by some whitish points on veins; an obscure whitish subterminal line; a terminal line interrupted on veins; cilia grey mixed with whitish. Hindwings with termen rounded; dark grey; basal area pale grey; cilia pale grey, apices whitish.

Western Australia: Collie in November; one specimen. Type in Coll. Lyell.

Scytrophanes amblyiodes, n. sp.

ἀμβλυωδης, dull, obscure.

♂. 45 mm. Head and thorax grey with some whitish hairs. Palpi 2½; grey, posterior surface fuscous. Antennae grey; pectinations in male 10, ochreous-fuscous. Abdomen grey-whitish. Legs grey; anterior pair fuscous with whitish irroration. Forewings rather narrow, suboblong, costa gently and uniformly arched, apex rounded, termen rounded, oblique; fuscous irrorated with grey-whitish so as to appear grey; a very short blackish median streak from base; two closely parallel fuscous transverse lines from one-fourth costa to one-third dorsum; two sinuate fuscous closely parallel lines from three-fourths costa to three-fourths dorsum; a subterminal series of fuscous dots; cilia grey. Hindwings about 1½, termen gently rounded; 6 and 7 coincident; grey-whitish with some grey suffusion near termen; cilia grey.

Very similar to *Gallaba eusciera*.

Tasmania: Hobart (Snug River, I. Harman) in April; one specimen in Coll. Lyell.

Genus Gallaba Wlk.

Recent discoveries show that this genus is not such a small one as was thought. As the species are very retired in their habits and rarely taken, we may expect further discoveries. Most of them are obscure and so closely similar as to require careful discrimination. The following key may be useful.

1.	Forewings with apex angled	2
	Forewings with apex rounded	3
2.	Forewings with subdorsal blackish streak from base	*cugraphes*
	Forewings without longitudinal streak from base	*ochropepla*
3.	Forewings with orbicular and reniform well-developed and touching	*diplocycla*
	Forewings with orbicular or both stigmata obsolete	4
4.	Forewings with short white streak from base	*basinipha*
	Forewings without white basal streak	5
5.	Forewings with reniform obsolete	*eusciera*
	Forewings with reniform distinct	6
6.	Forewings with reniform blackish-centred, narrow	*duplicata*
	Forewings with reniform not blackish-centred, not narrow	*dysthyma*

GALLABA DIPLOCYCLA, n. sp.

διπλοκυκλος, with double circles.

♀. 46 mm. Head whitish with a few dark fuscous scales. Palpi 2½; whitish, upper surface blackish. Antennae grey; pectinations in female 3½. Thorax dark fuscous with slight whitish irroration. Abdomen pale grey. Legs fuscous with whitish-grey hairs. Forewings oblong, costa arched near base, thence nearly straight, apex rounded, slightly oblique; grey; near base and on middle of costa suffused with whitish; two parallel sinuate blackish lines near base; two wavy transverse lines at one-fourth; orbicular and reniform circular, outlined with whitish and confluent, their centres blackish, the latter in middle; following these are three strongly sinuate slightly dentate lines at about two-thirds; a subterminal slightly dentate line; cilia grey. Hindwings grey becoming whitish towards base; cilia grey, on dorsum whitish.

New South Wales: Mittagong in November; one specimen. Type in Coll. Goldfinch.

GALLABA BASINIPHA, n. sp.

βασινιφος, with white basal mark.

♂. 48 mm. Head and thorax brown with white irroration. Palpi 3½; brown with white irroration. Abdomen whitish-grey. Legs brown with white irroration; posterior pair whitish-grey. Forewings elongate, narrow, costa moderately arched to middle, thence straight, apex rounded, termen slightly rounded, moderately oblique; fuscous-brown; a short slender white subdorsal streak from base; reniform represented by a short oblique slender fuscous bar with pale edges; some vague fuscous mottling but no defined markings; cilia fuscous. Hindwings ample, termen rounded, slightly sinuate; whitish-grey; cilia whitish-grey.

New South Wales: Mt. Kosciusko in December; one specimen. Type in Coll. Goldfinch.

GALLABA EUSCIERA, n. sp.

ευσκιερος, dark.

♀. 46 mm. Head and thorax fuscous irrorated with whitish. Palpi 2½; whitish irrorated with fuscous. Antennae whitish-grey; pectinations in female 3. Abdomen whitish-grey. Legs grey; anterior pair fuscous mixed with whitish. Forewings suboblong, costa evenly and moderately arched, apex rounded, termen rounded, scarcely oblique; fuscous uniformly and densely irrorated with whitish so as to appear grey without brownish tinge; markings fuscous; two faintly indicated transverse lines near base; two closely parallel dentate transverse lines from one-fourth costa to one-third dorsum; a wavy inwardly oblique line from

three-fifths costa to mid-dorsum; two closely parallel wavy sinuate transverse lines from three-fourths costa to two-thirds dorsum; an irregularly dentate subterminal line posteriorly edged with whitish; cilia grey. Hindwings with termen slightly sinuate; whitish, towards dorsum broadly fuscous-grey; cilia grey, apices paler.

New South Wales: Emmaville, near Glen Innes, in December; one specimen.

GALLABA DUPLICATA.

Gallaba duplicata Wlk., *Cat. Brit. Mus.*, xxxii, p. 458.

♂, ♀. 36-42 mm. Head and thorax fuscous-brown mixed with whitish. Palpi in male 3, in female 4; whitish mixed with fuscous. Antennae grey; pectinations in male 12, in female 5. Abdomen pale grey. Legs ochreous-whitish; anterior pair irrorated with fuscous-brown. Forewings suboblong, costa strongly arched near base, thence slightly, apex rounded, termen rounded, slightly oblique; pale grey irrorated throughout with fuscous-brown; markings fuscous, more developed in male; two short angulated lines from costa near base; two closely parallel irregularly dentate transverse lines from one-fourth costa to one-third dorsum; a small obliquely transverse mark margined with whitish in disc beyond middle; three closely parallel denticulate lines from about midcosta to beyond mid-dorsum, strongly outwardly curved around discal mark; an irregularly denticulate subterminal line; cilia pale fuscous, bases barred with pale grey. Hindwings with termen rounded; uniformly pale grey somewhat ochreous-tinged; cilia pale grey, apices whitish.

I have found it necessary to redescribe this species owing to its close similarity to the following.

Queensland: Brisbane; Stradbroke Island; Coolangatta. I have recorded this species also from Sydney, but would not now be sure of this locality.

GALLABA DYSTHYMA, n. sp.

δυσθυμος, gloomy.

♂. 48 mm.; ♀. 50 mm. Head fuscous with fine whitish irroration. Antennae fuscous; pectinations in male 10, in female 3. Palpi 3½; fuscous with whitish irroration. Thorax fuscous, sometimes brownish-tinged. Abdomen pale grey. Legs fuscous with some whitish irroration; posterior pair grey. Forewings suboblong, costa strongly arched to one-third, thence straight, apex rounded, termen rounded, scarcely oblique; fuscous sometimes brownish-tinged posteriorly; reniform small, obscure, slenderly outlined in pale grey; a dark fuscous crenulate line from beneath three-fourths costa to three-fourths dorsum, preceded by a faint parallel line; some longitudinal dark fuscous streaks before termen; cilia fuscous. Hindwings ample, termen rounded, sinuate; grey; cilia grey.

New South Wales: Mittagong in March and April; two examples in Coll. Goldfinch.

Genus DICERATUCHA.

Diceratucha Swin., *Ann. Mag. Nat. Hist.* (7), xiv, 1904, p. 133.

Face with a strong anterior chitinous process, excavated in middle. Tongue present but short. Palpi rather long, porrect, thickened with rough hairs; terminal joint concealed. Antennae of male shortly ciliated, becoming dentate towards apex. Thorax with short anterior and posterior crests; tegulae rather long, erect, and thickened towards apex. Posterior tibiae with two pairs of spurs. Forewings

with two from about four-fifths, 3 from shortly before angle, 5 from about midway between 4 and 6, 6 from below upper angle, areole rather large, 7 and 10 arising from it separately. Hindwings with 2 from about four-fifths, 3 from midway between this and angle, 5 from middle of cell, 6 and 7 stalked, 12 approximated to cell from base to about three-fourths. Type, *D. xenopis* Low.

This genus has been wrongly referred to the Oenochromidae, but should be placed in the Notodontidae near *Gallaba*. There is no trace of a humeral angle at the base of vein 12 of the hindwing, and the neuration is typically notodontid in every respect. This is confirmed by the scaling of the thorax and pattern of the forewings. Certainly the chitinous projection of the frons is exceptional in this family, but this is an adaptation to facilitate the emergence of the imago, and is common in Australia, especially in arid regions, in many genera of the Noctuidae, Boarmiadae, and Oenochromidae.

DICERATUCHA XENOPIS.

Oenone xenopis Low., *Trans. Roy. Soc. S. Aust.*, 1902, p. 227.—*Diceratucha xenopis* Swin., *Ann. Mag. Nat. Hist.* (7), xiv, 1904, p. 133.

♂, ♀. 25–35 mm. Head fuscous; frontal projection ending in an upper median and paired lateral acute spinous processes. Palpi fuscous. Antennae fuscous; in male simple and very shortly ciliated, becoming laminate towards apex. Abdomen grey. Legs fuscous with some whitish irroration; posterior pair mostly whitish. Forewings oval-triangular, costa strongly and uniformly arched, apex rounded, termen obliquely rounded; grey with some dark fuscous and whitish irroration; a blackish sinuate line from one-fourth costa to two-fifths dorsum, becoming strongly oblique towards dorsum; a small distinct circular orbicular spot at one-third, pale brownish edged with blackish; a similar but larger transversely oval reniform spot just beyond middle; a fuscous transverse median line, not always distinct, from before middle of costa, strongly angled outwards above middle, thence sinuate to dorsum beyond middle; a blackish line from beyond middle of costa, strongly curved outwards around reniform, then curved inwards to two-thirds dorsum, slightly dentate; a pale dentate subterminal line, sometimes indistinct; an interrupted blackish terminal line; cilia grey mixed with fuscous and whitish. Hindwings broad and ample, termen rounded and slightly bowed in middle; grey; terminal line and cilia as forewings.

New South Wales: Broken Hill; Bourke (Helms); Victoria: Birchip; Brentwood.

Family LIMACODIDAE.

PARASA DNOPHERA, n. sp.

δνοφερος, dark.

♀. 40 mm. Head fuscous with some whitish hairs. Palpi 2; dark fuscous. Antennae fuscous; in female slightly dentate. Thorax dark fuscous, anteriorly suffused with brownish. Abdomen dark fuscous; tuft whitish. Legs fuscous; tarsi annulated with whitish. Forewings triangular, costa straight to three-fourths, apex rounded, termen rounded, slightly oblique; 7 connate, 8, 9 stalked, 10 separate; dark fuscous; a subtriangular fuscous-brown dorsal blotch from one-third to tornus; apical area suffused with whitish, its anterior edge above blotch finely dentate; a fine blackish line, indented above middle, from four-fifths costa to tornus; cilia fuscous-grey. Hindwings with termen strongly rounded; fuscous; terminal edge, except towards tornus, suffused with whitish; cilia grey with a

whitish median line. Underside of both wings fuscous with a narrow whitish terminal suffusion.

North Queensland: Cape York in June; one specimen. Type in Coll. Barnard.

Thosea threnopis, n. sp.

θρηνωπις, mournful.

♂. 30–32 mm.; ♀. 40 mm. Head, thorax, palpi, abdomen, and legs brown. Antennae pale ochreous-grey; in male with a double row of moderate pectinations (3) continued almost to apex. Forewings elongate-triangular, costa straight to apex, apex rounded, termen strongly rounded, slightly oblique; 7, 8, 9 stalked, 10 separate (3 ♂, 1 ♀); dark brown broadly suffused with fuscous in median area; a straight oblique whitish line from five-sixths costa to two-thirds dorsum limits this suffusion posteriorly; a fuscous line immediately follows; terminal area paler; cilia brown. Hindwings with termen rounded; grey-brown; cilia grey-brown.

North Queensland: Cape York in November; four specimens received from Mr. W. B. Barnard, who has the type.

Genus Chalchoscelis.

To the definition of this genus should be added: Thorax with a posterior crest. Abdomen with dorsal crests. These are present in the type species, though not so pronounced as in that here described.

Chalchoscelis eulopha, n. sp.

εὔλοφος, well crested.

♂. 26 mm. Head dark fuscous; face mixed with brownish. Palpi 2, ascending; fuscous. Antennae fuscous; pectinations in male brownish, very long (12), ceasing rather abruptly at three-fifths. Thorax with bifid posterior crest; dark fuscous mixed with brownish. Abdomen with high bifid dorsal crest on first segment, very small crests on second and third segments; fuscous, towards apex pale brownish; basal crest anteriorly brown, posteriorly dark fuscous. Legs fuscous; tarsi and posterior tibiae brownish. Forewings oval-triangular, costa gently arched, apex rounded, termen obliquely rounded; 7 and 10 connate with 8, 9; fuscous; apical and terminal half brownish; a finely but irregularly dentate pale line from three-fifths costa to two-fifths dorsum; an outwardly curved fuscous line from four-fifths costa to tornus; cilia brownish obscurely barred with fuscous. Hindwings with termen strongly bowed; pale brown; cilia pale brown, apices whitish.

North Queensland: Cape York in June; one specimen. Type in Coll. Barnard.

Family Oenochromidae.

Genus Apotheta, n. gen.

ἀπόθετος, hidden.

Face not projecting, clothed with rough projecting hairs. Tongue strongly developed. Palpi moderate, porrect; second joint with long rough hairs beneath; terminal joint moderate, cylindrical, obtuse. Antennae in male bipectinate to apex. Thorax stout, densely hairy above and beneath. Femora hairy. Posterior tibiae with middle spurs. Tarsi spinulose. Forewings with areole long and narrow, 11 free, 9 and 10 long-stalked from cell, 9 anastomosing shortly with the stalk of 7 and 8. Hindwings with 3 widely separated from 2, approximated to 4, 5 from

middle of cell, 6 and 7 connate, 12 closely approximated to cell from near base to near its end.

Nearest *Phallaria* Gn., from which it differs by the frons not projecting, and the approximation of 3 and 4 of the hindwings to cell. From *Onycodes* Gn. it differs in the hairy face, palpi and thorax, and the long approximation of 12 of hindwings to cell. The type species has the cryptic coloration of many Boarmiadae.

Apotheta tanymita, n. sp.

τανυμιτος, with long threads.

♂. 38-44 mm. Head fuscous; face white. Palpi 2½; fuscous. Antennae grey-whitish; pectinations in male 6. Thorax and abdomen grey. Legs grey; posterior tibiae and tarsi mostly whitish. Forewings elongate-triangular, costa nearly straight but slightly sinuate before apex, apex acute, termen strongly rounded, oblique, dentate; grey with slight fuscous irroration; a median subcostal fuscous dot; a nearly straight but slightly waved fuscous line from one-fourth dorsum to middle of disc; a similar line edged anteriorly with whitish from mid-dorsum to just before apex, in one example gently and uniformly concave, in another rather strongly bisinuate; cilia dark grey, apices between dentations whitish. Hindwings with termen not rounded, dentate; as forewings, but without first line and with second line straight to just before costal end.

Western Australia: Merredin, in July; two specimens received from Mr. L. J. Newman.

Family Larentiadae.

Poecilasthena phaeodryas, n. sp.

φαιοδρυας, a dusky woodnymph.

♂. 33 mm. Head dark green; fillet narrowly white; face fuscous. Palpi minute; fuscous. Eyes in male enlarged, width of eyes considerably more than that of thorax. Antennae fuscous, towards base paler; ciliations in male minute. Thorax dark green. Abdomen dark green. Legs whitish-ochreous-grey. Forewings triangular, costa straight to middle, thence strongly arched, apex acute, slightly pointed, termen nearly straight but slightly sinuate; strongly oblique; dark green; a darker median subdorsal discal dot; slight white irroration forming numerous slender obscure interrupted or crenulate transverse lines; cilia dark green. Hindwings subquadrate, termen wavy, acutely angled on vein 4; as forewings but median discal dot at one-third.

Allied to *P. sthenommata* Turn., but much darker, white markings very obscure, termen of forewings not crenulate.

Queensland: National Park (3,000 ft.) in March; one specimen.

Chloroclystis plinthochyta, n. sp.

πλινθοχυτος, suffused with reddish.

♂, ♀. 16-19 mm. Head whitish; face pale reddish. Palpi 1½; fuscous. Antennae grey; ciliations in male minute. Thorax whitish with some reddish scales. Abdomen whitish; a dull reddish basal band on dorsum. Legs pale fuscous; posterior pair whitish. Forewings triangular, costa nearly straight, apex rounded, termen slightly rounded, oblique; whitish, towards base and termen with some fuscous suffusion, median area suffused with dull reddish; a suffused fuscous costal streak to two-fifths; a curved line from two-fifths costa to two-fifths dorsum, fuscous, anteriorly suffused, posteriorly sharply defined; a broad median

dull reddish fascia incomplete towards costa, its posterior edge ill-defined, with a short obtuse projection beneath costa; a fine indistinct whitish subterminal line; beyond this a fuscous suffusion interrupted by a whitish spot below middle; cilia fuscous. Hindwings with termen slightly bowed in middle; a subbasal fascia dull reddish mixed with fuscous; a postmedian fuscous line sharply angled in middle and beneath costa, preceded by some suffusion; a double subterminal line and some terminal suffusion fuscous; cilia whitish.

I formerly described this as the female of *C. pyrrholopha*, but I have both sexes and they are alike. The female of that species remains unknown.

North Queensland: Kuranda, near Cairns, in September and May; Millaa-millaa near Herberton, in November; three specimens.

CHLOROCLYSTIS CELIDOTA, n. sp.

κηλιδοτος, suffused.

♂. 18 mm. Head pale grey. Palpi 1¼; fuscous. Antennae grey; ciliations in male minute. Thorax fuscous; anterior margin pale grey. Abdomen fuscous, paler towards apex. Legs whitish; anterior pair fuscous. Forewings triangular, costa nearly straight, apex rounded, termen slightly rounded, oblique; whitish densely but not uniformly suffused with fuscous; lines slender, fuscous; antemedian from two-fifths costa to two-fifths dorsum, evenly curved; postmedian from three-fifths costa to three-fifths dorsum, curved, slightly and very obtusely angled above and below middle; both lines edged posteriorly by whitish lines; terminal area paler, with a whitish subapical suffusion; cilia whitish mixed with fuscous. Hindwings with termen rounded; fuscous; a large suffused whitish tornal blotch; a postmedian fuscous line, not angled; a similar subterminal line, slightly dentate; cilia as forewings.

North Queensland: Dunk Island in May; one specimen.

CHLOROCLYSTIS STENOPHRICA, n. sp.

στενοφρικος, narrowly rippled.

♀. 21–24 mm. Head whitish-grey with some fuscous scales. Palpi 2; fuscous with some whitish scales. Antennae grey. Abdomen grey with some fuscous irroration. Legs fuscous; tarsi narrowly ringed with whitish; posterior pair whitish. Forewings triangular, costa slightly arched, apex round-pointed, termen nearly straight, oblique; whitish with fuscous irroration and markings; the latter consist of numerous fine wavy transverse lines; antemedian from one-third costa to one-third dorsum, preceded by three parallel lines; postmedian from two-thirds costa to two-thirds dorsum, with a moderate acute posterior median angle, preceded by two finer lines and succeeded by another; a line from three-fourths costa to three-fourths dorsum parallel to postmedian and with similar acute median angle; a fine dentate whitish subterminal line; a blackish terminal line interrupted on veins; cilia fuscous with indistinct whitish bars opposite veins. Hindwings with termen bisinuate, only slightly rounded; pale grey; three pairs of fuscous dots representing short lines starting from dorsum, near base, at one-third, and between these; postmedian at two-thirds, consisting of a series of fuscous dots reaching middle, followed by a whitish line; another series of fuscous dots follows this; a faint whitish subterminal line; terminal line and cilia as forewings, but the latter paler.

Queensland: Bunya Mts. (3,500 ft.) in March; New South Wales: Ben Lomond (4,500 ft.) in February. Two specimens.

SCOTOCYMA TRANSFIXA, n. sp.

transfixus, pierced through.

♀. 33–36 mm. Head, thorax and abdomen fuscous-brown. Palpi 1¼; fuscous-brown with a few whitish scales. Antennae fuscous. Legs fuscous; tibiae and tarsi annulated with pale ochreous; posterior pair almost wholly pale ochreous. Forewings broadly triangular, costa moderately arched, apex rounded, termen rounded, oblique, crenulate; brown with numerous fine crenulate transverse fuscous lines; a fine white subbasal transverse line; a broad darker median band defined by fine white lines, anterior from one-third costa to one-third dorsum, slightly dentate, posterior from two-thirds costa to three-fourths dorsum, with rounded dentations, and a strong double median projection; a fine white line from base to termen along median vein; this emits a fine branch from costal side near base, which rejoins it at end of cell, forming a narrow loop; white lines from the end of this loop along veins 4 and 5 to termen; a fine white crenulate subterminal line; a fuscous terminal line; cilia fuscous-brown. Hindwings with termen rounded, dentate; as forewings but without subbasal and antemedian white lines, and with longitudinal white lines on veins 4 and 5 only. Underside ochreous-whitish with suffused fuscous transverse lines and discal dot and a narrow pale postmedian fascia on both wings.

Queensland: Jandowae near Dalby; National Park (3,000 ft.) in February; two specimens received from Mr. W. B. Barnard, who has the type.

LARENTIA TENUIS, n. sp.

tenuis, feeble.

♂. ♀. 24–25 mm. Head whitish sometimes ochreous-tinged. Palpi 1¼, rough-haired; dark fuscous, towards apex whitish. Antennae fuscous; pectinations in male 12, extreme apex simple. Thorax ochreous mixed with fuscous. Abdomen whitish-ochreous irrorated with fuscous; some median dorsal dots. Legs dark fuscous; tibiae and tarsi annulated with ochreous-whitish. Forewings triangular, costa gently arched, apex round-pointed, termen slightly rounded, moderately oblique; ochreous-whitish with fuscous and ochreous markings; a subbasal fuscous fascia connected with base along costa; a dentate ochreous transverse line doubly edged with fuscous at one-fourth; a moderately broad median fuscous band containing imperfectly developed darker crenulate lines, anterior edge wavy from one-third costa to one-third dorsum; towards costa the band contains a whitish area in which is a rather large round blackish median discal spot; beyond band is a whitish line, followed by a fuscous-edged fine ochreous line; a fine crenulate whitish subterminal line; term n l area fuscous interrupted by subapical and median whitish spots; an interrupted dark fuscous terminal line; cilia fuscous with several whitish-ochreous bars. Hindwings with termen rounded; grey; a fuscous median dot at one-third; obscurely paler wavy post-median and subterminal lines; cilia whitish-ochreous barred with fuscous.

Queensland: National Park (3,000–4,000 ft.) in March; four specimens.

Family GEOMETRIDAE.

CHLOERES PRASOCHROA, n. sp.

πρασοχροος, green like a leek.

♂. 25 mm. Head green; fillet whitish; face pale-green. Palpi 1, slender; whitish. Antennae white; pectinations in male 10. Thorax and abdomen green. Legs whitish. Forewings triangular, costa arched at base, thence straight to four-

fifths, apex pointed, termen slightly rounded, slightly oblique; green; costal edge whitish from near base to apex; transverse lines very slender, whitish, indistinct; antemedian from one-fourth costa to one-third dorsum, nearly straight; postmedian from five-sixths costa to three-fourths dorsum nearly straight; cilia whitish. Hindwings with termen slightly bowed on vein 4; colour and cilia as forewings; an elongate semilunar whitish mark in middle with concavity posterior; postmedian at three-fourths, curved, slightly wavy.

North Queensland: Charters Towers, in August; one specimen.

Family Noctuidae.

Dasygaster atrata, n. sp.

atratus, clothed in black.

♂. 40–42 mm. Head and thorax blackish. Palpi 1; external surface blackish except apices of joints, these with anterior and internal surfaces pale grey. Antennae blackish; in male biciliated in tufts, each tuft accompanied by a slightly longer bristle (1). Abdomen fuscous. Legs fuscous; tarsi with whitish rings. Forewings elongate-triangular, costa very slightly arched, apex rectangular, termen straight, crenulate, rounded beneath, not oblique; dark fuscous with obscure blackish markings; an obscure series of costal spots; three minute whitish dots on posterior fourth of costa; orbicular small, longitudinally oval, pale with darker centre, suffusedly surrounded with blackish; reniform larger, containing a dark ring; claviform represented by a blackish suffusion; a fine irregularly dentate transverse line at two-thirds; some longitudinal streaks in terminal area; a fine pale dentate subterminal line, sometimes obsolete; cilia dark fuscous with a fine pale basal line. Hindwings with termen bisinuate, wavy; fuscous; paler near base; cilia fuscous, apices and bases paler.

New South Wales: Ben Lomond (4,500 ft.) in February; three specimens.

Genus Cyclopރora, n. gen.

κυκλοπρωρος, with rounded prow.

Tongue strong. Palpi moderate, ascending, shortly rough-scaled; terminal joint very short, obtuse. Antennae in male simple, minutely ciliated. Face smooth, rounded, prominent. Thorax with anterior and posterior crests. Abdomen with crests on basal and third segments, minute crests on following segments. Posterior tibiae rough-haired on dorsum. Hindwings with cell 3/5; 3 and 4 separate, 5 obsolete from middle of cell, 6 and 7 connate.

Allied to *Cosmodes* Gn., with which it agrees in the long cell of hindwing, but differs in the prominent face.

Cyclophora aridoxa, n. sp.

ἀριδοξος, splendid.

♂. 28 mm. Head brown; face white. Palpi 1; blackish, terminal joint and apex of second joint white. Antennae dark fuscous; ciliations in male minute. Thorax blackish; an anterior brown spot; tegulae except bases pale-green. Abdomen whitish; a median dorsal series of blackish spots. Legs blackish; tibiae and tarsi with white rings; posterior pair more whitish. Forewings rather broadly triangular, costa gently arched, apex rectangular, termen rounded, towards tornus wavy, not oblique; green, white, and brown, with blackish markings; basal area and a quadrangular subcostal blotch about middle white, remaining area green; a spot on base of costa prolonged towards, but not reaching a dot on dorsum

near base; costal edge white interrupted by blackish bars; an outwardly curved transverse line at about one-fifth, edged anteriorly white, preceded by a suffused brown spot, followed by a confluent quadrangular subcostal spot and a short longitudinal bar below middle; a triangular spot with base towards costa indents the median white area; postmedian line from beneath two-thirds costa to two-thirds dorsum, forming a posterior median rounded prominence, edged white posteriorly, followed by a brown fascia, which does not reach margins; a similar but finer subterminal line; a fuscous tornal blotch and a smaller one on apical part of termen; cilia whitish with dark fuscous bars. Hindwings with termen rounded; whitish towards base; a bisinuate postmedian grey line; terminal area grey; cilia whitish with a grey median line.

Queensland: Toowoomba, in March; one specimen received from Mr. W. B. Barnard, who has the type.

BATHYTRICHA PHAEOSTICHA, n. sp.

φαιοστιχος, dark-lined.

♂, ♀. 20–26 mm. Head fuscous or fuscous-whitish. Palpi 1; fuscous. Antennae ochreous-whitish; in male shortly bipectinate. Thorax grey-whitish, anteriorly more or less fuscous. Abdomen whitish-grey. Legs fuscous-whitish or whitish. Forewings elongate-triangular, costa nearly straight, apex rounded-rectangular, termen not oblique, rounded beneath; grey-whitish; a pale fuscous longitudinal median streak more or less developed; sometimes also slender streaks beneath costa, above dorsum, and on veins in terminal area; an obscure postmedian series of fuscous dots; a more distinct series of terminal dots; cilia grey-whitish. Hindwings with termen rounded; whitish; cilia whitish.

Queensland: Bunya Mts. (3,500 ft.) in February and March; a series taken at light.

DINOPRORA STALIDOSEMA, n. sp.

σταλιδοσημος, peg-marked.

♂, ♀. 30–32 mm. Head and thorax fuscous. Palpi 1¼; whitish-ochreous; basal two-thirds of outer surface of second joint dark fuscous. Antennae fuscous; ciliations in male very short (¼). Abdomen whitish-grey. Legs fuscous; tibiae and tarsi with whitish rings; posterior pair mostly ochreous-whitish. Forewings elongate-triangular, costa straight, apex rounded-rectangular, termen moderately rounded, slightly oblique; brownish-fuscous; some minute brownish costal dots; a fine indistinct fuscous line from one-fourth costa to one-third dorsum; orbicular small, round, brownish; reniform brown-whitish with a central fuscous line continuous with ground-colour beneath, its outer inferior angle shortly produced; a fine crenulate fuscous postmedian line from two-thirds costa to two-thirds dorsum, curved outwardly to below middle, thence inwardly; some indistinct brownish dots representing subterminal line; a fine interrupted terminal line; cilia fuscous, apices pale brownish. Hindwings ample, termen slightly sinuate; whitish with some grey suffusion towards termen; a fine interrupted terminal line; cilia whitish.

New South Wales: Bourke (Helms); Broken Hill, in April; two specimens.

CARADRINA ARGONEPHRA, n. sp.

αργονεφρος, with white reniform.

♂, ♀. 30 mm. Head and thorax brownish-fuscous. Palpi 1½; fuscous; anteriorly towards apex brown-whitish. Antennae fuscous; ciliations in male short (2/3). Abdomen grey. Legs fuscous. Forewings triangular, costa straight; apex rounded-rectangular, termen slightly rounded, scarcely oblique; brownish-fuscous; markings fuscous; a costal spot at one-fourth giving rise to a fine crenulate line to one-third dorsum; orbicular indicated by a minute pale dot; reniform rather small, shining white; outlined with fuscous, closely preceded by a slender pale transverse line; a faint median line, obsolete towards costa; postmedian double from two spots on costa beyond middle, strongly curved outwards, then inwards and wavy to two-thirds dorsum; sometimes a series of longitudinal streaks before termen, interrupted by a pale subterminal line; a terminal line; cilia fuscous. Hindwings with termen slightly sinuate; pale grey; cilia pale grey.

Differs from *C. confinis* Wlk. in the shorter broader forewings and absence of plical streak, as well as the white reniform, which may not be constant.

Western Australia: Perth; two specimens received from Mr. W. H. Matthews.

Caradrina asbolaea, n. sp.

ἀσβολαιος, sooty.

♂, ♀. 28–30 mm. Head fuscous. Palpi 1¼; fuscous; apices of second and terminal joints whitish. Antennae fuscous; ciliations in male short (2/3). Thorax fuscous; apices of patagia narrowly whitish. Abdomen and legs grey. Forewings elongate-triangular; costa straight except at base and apex, apex rounded-rectangular, termen slightly rounded, scarcely oblique; fuscous; orbicular indicated by a minute whitish dot; reniform very small, rounded or transversely oval, whitish or brownish; cilia fuscous. Hindwings with termen rounded; grey; cilia grey.

Victoria: Birchip, in April (Goudie); two specimens.

Genus Clytoscopa, n. gen.

κλυτοσκοπος, of noble appearance.

Tongue strongly developed. Frons not projecting, but with a superior tuft. Palpi long, ascending, reaching vertex; second joint long, densely thickened with appressed scales, which form a small posterior apical tuft; terminal joint moderate, porrect, partly concealed. Antennae of male shortly ciliated. Thorax with a posterior crest. Abdomen without crests. Posterior tibiae almost smooth. Forewings with 2 from about two-thirds, 7, 8, 9 stalked from areole, 7 arising before 9, 10 arising separately from areole or 10 disconnected and areole absent. Hindwings with cell about two-fifths, 3 and 4 connate, 5 well developed from about one-fourth, 6 and 7 connate, 12 anastomosing strongly with cell at one-fourth.

Allied to *Cerynea* and *Hyposada*. Differs from both in the structure of the palpi, the thoracic crest, the strong anastomosis of 12 with cell of hindwing, and the absence of stalking of 3 and 4; from *Cerynea* in the longer cell of hindwings, which is, however, shorter than in *Hyposada*. Type, *C. iorrhoda*.

Clytoscopa iorrhoda, n. sp.

ἰοῤῥοδος, purple-rosy.

♂, ♀. 28–30 mm. Head reddish-brown. Palpi 2; reddish-brown. Antennae fuscous; ciliations in male ½. Thorax reddish-brown; tegulae violet-tinged. Abdomen ochreous-grey-whitish. Legs reddish-violet; anterior pair and middle tibiae fuscous. Forewings triangular, costa gently arched, more strongly towards apex,

apex pointed; termen straight, but with a strong projecting tooth on vein 4; brown, partly and irregularly suffused with violet-rosy; on costa this is interrupted by four suffused brown spots at one-sixth, one-third, middle and two-thirds; a fuscous line from base along fold to one-sixth, then angled and straight to touch second costal spot, there right-angled and straight to lower angle of cell; an oblique fuscous line from mid-dorsum to vein 3 shortly beyond cell, its extremity in a line with terminal part of first line; an inwardly-oblique sinuate line from three-fourths costa, sharply curved outwards above middle, and again sinuate almost to termen, then describing a hairpin bend and joining extremity of second line; these lines are partly edged with white and rosy above and posteriorly; similar short lines from near base of dorsum to first angle of first line, and from three-fourths dorsum to vein 2, connecting first and second lines above middle; three short longitudinal lines running into termen, and an irregular spot between the first and second of these; cilia brown with several fuscous bars. Hindwings with termen rounded, bisinuate; reddish-violet with a paler median band and basal area; a terminal series of fuscous dots, into which run short suffused fuscous lines; cilia ochreous-whitish.

Very distinct and remarkable in colour and pattern.

Queensland: Bunya Mts., in November; four specimens received from Mr. W. B. Barnard, who has the type.

CLYTOSCOPA SERENA, n. sp.

serenus, clear, bright.

♂. 26–28 mm. Head and thorax purple-brown. Palpi long, ascending, appressed to frons; second joint long, exceeding vertex with a small posterior tuft of scales; terminal joint short porrect. Antennae fuscous; ciliations in male 1. Abdomen whitish-ochreous. Legs whitish-ochreous; anterior and middle pairs crimson-tinged. Forewings triangular, costa slightly arched, more strongly towards apex, apex acute, termen with a strong acute tooth on vein 3; 7, 8, 9 stalked, 10 disconnected; purple-brown; marked with white lines partly suffused with purple-rosy; two short diverging lines from base parallel to costa and dorsum; an inwardly oblique line from one-third costa, bent at a right angle in middle, and thence straight to mid-dorsum; a posterior line from three-fourths costa to mid-dorsum, interrupted in middle; a fine longitudinal line in disc between these; five short longitudinal lines running into termen, with some pale suffusion between them; cilia brown. Hindwings with termen rounded; dull purple-rosy becoming whitish-ochreous near base; cilia purple-rosy.

Similar in colour, though different in pattern, to the preceding. Probably they are cryptic in both cases.

Queensland: Toowoomba, in September; Bunya Mts., in November; four specimens received from Mr. W. B. Barnard, who has the type.

EUPRORA CRYPSICHLORA, n. sp.

κρυψιχλωρος, with hidden green.

♂, ♀. 26–28 mm. Head and thorax brown-whitish with some fuscous irroration. Palpi 1½; fuscous mixed with brown-whitish. Antennae fuscous; ciliations in male 1, in female ½. Abdomen grey-whitish with fuscous irroration. Legs fuscous; tibiae and tarsi with brown-whitish rings. Forewings triangular, costa scarcely arched, apex rectangular, termen slightly rounded, scarcely oblique; pale fuscous, faintly greenish-tinged, mixed with darker fuscous; basal area paler, with

an incomplete, outwardly curved, transverse line near base; a darker transverse fascia before middle; its anterior edge concave and preceded by a fine fuscous parallel line, between these above middle is a small oblique whitish spot representing orbicular; posterior edge with an acute median tooth above which rests the reniform, rather large, whitish, with a fine included oval line; costa with pale spots at one-fourth, one-half, and three dots between last and apex; a darker subterminal shade, ill-defined anteriorly, with large irregular projections above and below middle; an interrupted dark fuscous terminal line; cilia fuscous. Hindwings with termen rounded, bisinuate; pale fuscous; a fuscous terminal line; cilia pale fuscous.

This differs from the two species of *Euprora* previously described in the shape of the forewings, which are triangular and not elongate.

Queensland: Bunya Mts. (3,500 ft.) in February and March; a series taken.

Family Psychidae.

PLUTORECTIS PANTOSEMNA, n. sp.

παντοσεμνος, grand, stately.

♂. 38 mm. Head, thorax, abdomen, and legs orange. Palpi blackish. Antennae blackish; pectinations 10. Forewings (apices damaged) orange; a thick black costal streak. Hindwings with termen strongly rounded; orange.

The finest Australian species.

Western Australia: Lennox; one specimen taken by Mr. J. K. Ewers. Type in Coll. Lyell.

Family Phycitidae.

ERNOPHTHORA MILICHA, n. sp.

μειλιχος, gentle.

♂, ♀. 18 mm. Head whitish. Palpi 2½, ascending; whitish mixed with dark fuscous; terminal joint wholly dark fuscous. Antennae grey; in male thickened, slightly laminate, minutely ciliated. Thorax and abdomen whitish. Legs whitish-grey; tibiae and tarsi with whitish rings; anterior pair mostly fuscous. Forewings narrow, posteriorly dilated, costa gently arched, apex round-pointed, termen slightly rounded, slightly oblique; white suffused with pale grey; a blackish dot on fold at one-fifth, longitudinally elongate, another subcostal at two-fifths; sparsely scattered blackish scales in disc beyond this, these tend to form a minute median dot, and another beneath two-thirds costa; a fine blackish terminal line; cilia pale grey, apices white, with a fine blackish median line. Hindwings 2½; termen gently rounded; whitish; a fine fuscous terminal line; cilia as forewings.

Agrees exactly with Meyrick's generic definition, but in one hindwing of the female example vein 5 separates just before termen.

Queensland: Yeppoon, in October; National Park (3,000 ft.) in March; two specimens.

Genus Creobota, n. gen.

κρεοβοτος, carnivorous.

Tongue absent. Maxillary palpi large with broadly dilated tuft of scales at apex. Labial palpi curved, ascending; second joint long, thickened with appressed scales; terminal joint short, stout at base, acute. Forewings with 4 and 5 stalked, 8 and 9 stalked. Hindwings with cell over one-half, 2 from well before angle of cell, 4 and 5 stalked.

Except that the cell of hindwings is longer, this agrees in neuration with *Hypargyria* Rag., but differs in the absence of a tongue and the broadly dilated maxillary palpi. It has, I believe, no near relationship to the Anerastianae.

CREOBOTA COCCOPHTHORA, n. sp.

κοκκοφθορος, destroying scale insects.

♀. 21–22 mm. Head and thorax fuscous. Palpi fuscous, towards base whitish. Antennae grey. Abdomen brownish; apices of segments whitish; basal segment grey. Legs dark fuscous irrorated, and tarsi ringed, with whitish; middle and posterior tibiae mostly white. Forewings narrow, dilated posteriorly; costa straight, apex rounded, termen rounded, slightly oblique; fuscous-grey; costal area broadly suffused with white; a dark fuscous median dot at one-fourth; a blackish dot above middle at two-thirds; an oblique fuscous shade from apex sharply defined anteriorly; cilia grey, on apex fuscous.

Black Mt., Canberra, in May; three specimens received from Mr. A. L. Tonnoir, with the following life history: "The Phycitid caterpillar has a curious mode of life. It builds a protective sheath in the shape of a very loose and flexible cocoon without leaving any definite opening. The outside of this cocoon is sticky, so that it gets a good hold on the twigs among the scale insects. When the larva wants to displace itself, it walks in this cocoon, which rolls round its body, just as would happen in the case of a person sewn inside a sack and trying to progress by walking on all fours. When the caterpillar wants to feed, it pokes its head anywhere through the rather loose walls of this sheath." The scale was an *Eriococcus*.

Family PYRAUSTIDAE.

SCOPARIA EUTACTA, n. sp.

εὐτακτος, neat.

♂. 17 mm. Head whitish; face grey. Palpi 2; white with a broad fuscous median band. Maxillary palpi fuscous. Antennae grey; ciliations in male minute. Thorax fuscous with some whitish scales in patagia and tegulae. Abdomen grey; tuft and underside whitish. Legs white; tibiae (except posterior) and tarsi broadly ringed with blackish. Forewings narrowly triangular, costa straight to near apex, apex pointed, termen nearly straight, oblique; white with general blackish irroration; a curved antemedian white transverse line at one-fourth, its outer edge broadly blackish; confluent with this are two brown-blackish spots, above and below middle, representing probably orbicular and claviform; some blackish dots on costa; an irregular brown-blackish spot at two-thirds representing reniform, and another at five-sixths, both confluent with costal spots; postmedian line sinuate, white, ill-defined; a series of blackish spots on termen and tornus; cilia white with an interrupted blackish subbasal line. Hindwings with termen sinuate; whitish; cilia whitish with a faint grey antemedian line.

Best characterized by the narrow forewings, in which typical spots are replaced by small brown-blackish suffusions confluent with other markings.

Queensland: National Park (4,000 ft.) in March; two specimens received from Mr. W. B. Barnard.

SCOPARIA NIPHETODES, n. sp.

νιφετωδης, snowy.

♂, ♀. 16 mm. Head blackish. Palpi 1½; blackish; at base white. Antennae whitish becoming fuscous near base; ciliations in male minute. Thorax white;

patagia fuscous. Abdomen whitish. Legs whitish; anterior and middle tibiae and tarsi with fuscous annulations. Forewings narrowly triangular, costa straight to near apex, apex rounded, termen nearly straight, slightly oblique; white; basal markings represented by some scattered blackish scales forming a very slight subbasal suffusion, and a triangular mark on costa before middle connected by a line with one-third dorsum; a fine wavy blackish line from three-fourths costa to three-fourths dorsum, preceded by a small dorsal suffusion; apical area except terminal edge rather densely suffused; cilia white with several blackish dots on apices. Hindwings with termen sinuate; whitish; cilia whitish.

Characterized by the general white colour of forewings with loss of discal spots and much reduced markings.

Queensland: Bunya Mts. (3,000 ft.) in January; four specimens.

SCOPARIA PLAGIOTIS.

Scoparia plagiotis Meyr., *Trans. Ent. Soc.*, 1887, p. 247.—*Scoparia ochrophara* Turn., *Proc. Roy. Soc. Q.*, 1915, p. 52.

New South Wales: Mt. Kosciusko (3,500 ft.); Victoria: Gisborne; Tasmania: Hobart, Campbell Town, Strahan.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE ACTINOMYCETALES. II.

THE DEFINITION AND SUBDIVISION OF THE GENUS ACTINOMYCES, WITH A PRELIMINARY ACCOUNT OF AUSTRALIAN SOIL ACTINOMYCETES.

By H. L. JENSEN,
Macleay Bacteriologist to the Society.

(Plates xix–xx.)

[Read 30th September, 1931.]

Introduction.

Few groups of microorganisms have caused more confusion in systematic respect than the genus *Actinomyces*. This confusion exists firstly as to the nomenclature, secondly as to relation to other genera and families, and thirdly in the problem whether *Actinomyces* should be included in the bacteria at all or relegated to the *Fungi imperfecti*.

Since Cohn (1875) first described an *Actinomyces* (termed *Streptothrix* by him), more names have been given to this than to any other genus of bacteria. Breed and Conn (1919), who have revised the question of nomenclature very carefully, conclude that *Actinomyces* Harz (1877) is the only valid generic name, but it is still quite common to meet the names *Streptothrix* and *Nocardia* in medical literature. Most of the earlier authors (Almquist, 1890; Boström, 1890; Kruse, 1896) regarded these organisms as "pleomorphic bacteria", and several points of similarity between them and the tubercle and diphtheria bacilli were discovered, such as the branching growth of the latter organisms, acid-fastness, and the ability of the tubercle bacillus and related forms to produce an actinomycosis-like growth in the animal organism. Lachner-Sandoval (1898) was the first to unite *Actinomyces* with the genera *Mycobacterium* and *Corynebacterium* (Lehmann and Neumann, 1896) into a family *Actinomycetes*. This name has later been altered to *Actinomycetaceae* by Buchanan (1918), who also (1917) erected an order *Actinomycetales*. This uniting of *Actinomyces*, *Mycobacterium* and *Corynebacterium* has been adopted in most treatises on systematic bacteriology (Lehmann and Neumann, 1896-1927; Orla-Jensen, 1909; Castellani and Chalmers, 1919; Bergey, 1923-1930; Enderlein, 1925; Janke, 1929; and several others), although the nomenclature is not uniform, and opinions are divided as to whether this group of organisms should be considered an Order (Buchanan, Bergey, Lehmann and Neumann) or only a family (Enderlein, Janke).

In the most recent edition of Lehmann and Neumann's Bakteriologische Diagnostik (1927) we find the following system of classification:

Order.	Family.	Genus.
Actinomycetales	Proactinomycetaceae	*Corynebacterium*
		Mycobacterium
	Actinomycetaceae	*Actinomyces*

The family name *Mycobacteriaceae* (Chester, 1897, cit. after Buchanan, 1925) has here been replaced by *Proactinomycetaceae* L. and N.

In the various editions of Bergey's Manual of Determinative Bacteriology (1923-1930) we meet an ever-increasing tendency to make the Order *Actinomycetales* what the *Fungi imperfecti* are among the Eumycetes—a heterogeneous collection of forms which cannot conveniently be placed elsewhere in the system. In the last edition (1930) the main points in the definition of *Actinomycetales* are: "Cells usually elongated, frequently filamentous and with a decided tendency to the development of branches, in some genera giving rise to the formation of a definite branched mycelium.—Usually Gram-positive. Non-motile. . ."

The Order is represented by two families—*Actinomycetaceae* and *Mycobacteriaceae*. The former contains *Actinomyces*, *Actinobacillus*, *Leptothricia*, and *Erysipelothrix*, the latter *Mycobacterium*, *Corynebacterium*, *Mycoplana*, *Fusiformis*, *Pfeifferella*, *Cytophaga*, *Cellvibrio*, and *Cellfalcicula*. The genus *Actinobacillus* Lignières and Spitz (1904) is, as pointed out by Magnusson (1928), hardly more related to *Actinomyces* than is the coli bacillus; the evidence brought forth by Nepomnjaschy (1930) in favour of a cyclogenetical relationship between *Actinobacillus* and *Actinomyces* is not entirely convincing. The genera *Leptothricia* and *Erysipelothrix* resemble *Actinomyces* only in the formation of filaments under certain conditions, which is true of many other bacteria, and the former genus lacks the property of branching which should characterize the Order Actinomycetales. As to the genera of Mycobacteriaceae, *Mycoplana* Gray and Thornton (1928) has been very little studied; it may possibly be closely related to *Mycobacterium*, as a motile parallel to this, but in that case the definition of Actinomycetales should not include non-motility as a constant character. The position of *Pfeifferella*, the organism of glanders, is doubtful; it is generally considered closely related to the corynebacteria, although Ørskov (1923) expresses grave doubt as to this. *Fusiformis* seems, as shown by Sanarelli (1927), to be related to the spirochetes rather than to the actinomycetales. Finally, as to the genera *Cytophaga*, *Cellvibrio*, and *Cellfalcicula*, it is hardly possible to see any valid reason for including them in the actinomycetales. *Cellvibrio* Winogradsky (1929) seems to differ from the familiar genus *Vibrio* only in its power of decomposing cellulose, and it may well be questioned whether this is a valid reason for making it a separate genus (*cf.* Kalninš, 1930). In the same way *Cellfalcicula* Winogradsky (1929) seems quite indistinguishable from *Cellulomonas* McBeth and Scales, a genus which Bergey places under the Order Eubacteriales; of this genus, Skinner (1929) has aptly pointed out that the power of decomposing cellulose is no valid reason for establishing it as a genus apart from *Bacterium*. The genus *Cytophaga* Winogradsky (1929) also lacks every point of resemblance to the actinomycetales. Its "sporoids" are, as pointed out by Winogradsky, apparently homologues of the globular bodies in the fusiform bacteria, which seem to be close relations of the spirochetes (Sanarelli, 1927). Upon the whole Lehmann and Neumann's classification seems by far the most logical and workable and has therefore been followed here.

Several attempts have been made to split *Actinomyces* into two or more genera. Wright (1905) would reserve the name *Actinomyces* for the anaerobic or microaerophilic organisms known to produce actinomycosis in man and cattle (the type of Wolff and Israel, 1891); for the aerobic forms he suggested the use of the name *Nocardia* (Trevisan, cit. after Buchanan, 1925). Haass (1906) would use the names *Actinomyces* for the aerobic and *Actinobacterium* for the anaerobic type,

and proposed to transfer those actinomycetes which produce a soft, bacterium-like growth, e.g. *Act. farcinicus* Nocard (1888), to the genera *Mycobacterium* and *Corynebacterium*. Pinoy (1913) followed Wright's division into an aerobic type, *Nocardia*, and an anaerobic type for which he substituted the name *Cohnistreptothrix* for *Actinomyces*. Wollenweber (1921) distinguished two subgenera under *Actinomyces: Aerothrix* with, and *Pionnothrix* without, aerial mycelium. A rational attempt to subdivide *Actinomyces* on the basis of definite morphological features was made by Ørskov (1923), who distinguished the following three groups:

I. Organisms which form a unicellular, non-septate vegetative mycelium, and an aerial mycelium composed of hyphae, thicker than those of the vegetative mycelium and dividing into spore-like bodies of regular and uniform size and shape. The name *Cohnistreptothrix* was suggested for this group.

II. Organisms in which the vegetative as well as the aerial mycelium divide by septa into pieces of irregular size and shape, without any spore-like bodies as in Group I. The aerial mycelium is absent in one subgroup, in which there is also a tendency to adopt the "angular" growth characteristic of the mycobacteria and corynebacteria which, it is contended, should really be included in this group, for which it was proposed to reserve the name *Actinomyces*.

III. Organisms which form a unicellular mycelium without aerial hyphae, but with spore-like bodies borne singly on the tips of short branches of the vegetative hyphae. It was proposed to call this group *Micromonospora*.

Ørskov's work marks a great step towards a better understanding of the natural relationships of the order we are dealing with, but his nomenclature (which, indeed, he himself only claims to be tentative) is less fortunate, since the name *Cohnistreptothrix* was first intended by Pinoy (1913) to be applied to anaerobic, pathogenic forms which, as Ørskov himself shows, at least partly belong to Group II, for which Ørskov would reserve the name *Actinomyces*. Further, Castellani and Chalmers (1919), who adopt Pinoy's nomenclature, give a list of not less than nine species of *Cohnistreptothrix* in the sense of Pinoy. An unreserved adoption of Ørskov's nomenclature, as regards Groups I and II, could, therefore, easily lead to confusion.

As mentioned above, the tendency among most of the earlier authors was to regard the actinomycetes as "pleomorphic bacteria". Sauvageau and Radais (1892), on the other hand, considered them true fungi of the genus *Oospora*, and Lachner-Sandoval (1898) would transfer *Actinomyces* as well as *Mycobacterium* and *Corynebacterium* to the *Fungi imperfecti* because of their branching growth, which was thought to be incompatible with the nature of bacteria. Notwithstanding the fact that *Actinomyces* has been included in nearly all classifications of bacteria, there has been a good deal of controversy whether these organisms should be regarded as "true bacteria" or fungi. In more recent time the tendency has mostly been to regard them as a special group of microorganisms, apart from both the fungi and the bacteria (Waksman, 1919; Lieske, 1921; Ørskov, 1923), and in most papers on the subject we meet the following statement, somewhat varied in its verbal expression: "The actinomycetes occupy an intermediate position between the bacteria and the fungi". Claypole (1913) regards them as an ancestral type of microorganism, giving rise, on one side to yeasts and higher filamentous fungi, and on the other to mycobacteria, corynebacteria, and ordinary bacteria. Lieske (1921) pointed out that there is a much wider gap between the actinomycetes and the simplest hyphomycetes (e.g. *Oidium lactis*) than between bacteria and

certain types of actinomycetes. Drechsler (1919) regarded the genus *Actinomyces* as entirely conforming with the hyphomycetes and devoid of any bacterial characteristics. It is obviously Drechsler's limitation of his fine morphological work to organisms of Ørskov's Group I, which has led him to this rather extreme view.

The present work represents a study of the morphology and biology of about 70 strains of *Actinomyces* isolated from various Australian soils, with the purpose of obtaining a more solid systematic basis for the study of this important group of soil microorganisms. Special attention was given to the work of Ørskov; the genus *Micromonospora* proposed by him has been made the subject of a preliminary account previously (Jensen, 1930*a*). The non-systematic term "actinomycetes" or "ray fungi" covers *Micromonospora* as well as the organisms of Ørskov's Groups I and II—filamentous organisms of a definitely mycelial growth, of bacterial dimensions, and generally producing an aerial mycelium. As the Order Actinomycetales we shall regard these organisms as well as the genera *Mycobacterium* and *Corynebacterium*, which, as most investigators agree, form a natural group of microorganisms.

Experimental.

The organisms included in this study were obtained partly from soil samples from lawns and flower beds in the grounds of Sydney University (here designated by the characters AI, AII, AIII, U, and G), partly from a number of samples in the collection of soils in the School of Agriculture, Sydney University; these latter are designated by the figures 6, 92, 125, 129, 130, 148, 163, and 176.

Isolations were in most cases carried out by plating on a dextrose-casein-agar medium previously described (Jensen, 1930*a*, 1930*b*). In a few cases soil was inoculated into a mineral nutrient solution with phenol or paraffin as source of energy, and platings were made therefrom, when a growth of microorganisms had taken place. The following media were used for studying the cultural characters of the organisms.

1. Saccharose agar.—Saccharose 20·0 gm.; $NaNO_3$ 2·0 gm.; K_2HPO_4 1·0 gm.; $MgSO_4$ 0·5 gm.; agar 15·0 gm.; water 1,000 c.c.

2. Dextrose agar.—Dextrose, 10·0 gm.; asparagin 1·0 gm.; K_2HPO_4 0·5 gm.; $MgSO_4$ 0·5 gm.; agar 15·0 gm.; water 1,000 c.c.

3. Nutrient agar.—Meat extract 5·0 gm.; peptone 10·0 gm.; dextrose (in some cases glycerin) 10·0 gm.; agar 15·0 gm.; water, 1,000 c.c.

4. Dextrose broth.—Same, without agar.

5. Potato.—6. Milk.—7. Gelatin (15% gelatin in tap water, pH 7·0).

Diastatic activity was tested on agar containing 1% soluble starch, 0·2% $NaNO_3$, 0·1% K_2HPO_4, and 0·05% $MgSO_4$. A corresponding mineral solution was used, with strips of filter paper for testing the power of decomposing cellulose, and with flakes of paraffin wax for determination of ability to utilize paraffin. Invertase-production was tested in a solution corresponding to medium 1. Resistance to hydrogen-ion concentration was tested by measuring the reaction (colorimetrically) in a physiologically acid nutrient solution (dextrose 2·0%, NH_4Cl 0·2%, K_2HPO_4 0·02%, $MgSO_4$ 0·05%) after three weeks' incubation. With some of the strains, a study of the ability to utilize various sources of carbon (pentoses, mono- and disaccharides, higher alcohols) was carried out. The above-mentioned solution with $NaNO_3$ and mineral nutrients was used in this case, where tests were also made for the reduction of nitrate to nitrite. A complete set of experiments with all the strains was not carried out, since there is little hope of obtaining any distinct species differen-

tiation by means of these tests (Waksman, 1919; Jensen, 1930*b*). All cultures were incubated at 28–30° C., unless otherwise stated, at which temperature they made an excellent growth. For morphological studies the dextrose-casein-agar (in the following simply called casein agar) was mostly used; the thin, spreading growth produced by most organisms on this medium makes it well adapted for direct microscopical study of the growth on open agar blocks (Ørskov, 1923) by means of high-power dry lenses. This was found the only quite satisfactory method for studying the aerial mycelium in its natural arrangement, although good results, particularly for photography, were also obtained with a simplification of the method of Drechsler (1919): a clean cover slip is pressed gently against the aerial mycelium, lifted without any lateral sliding, the adhering material is fixed with formalin vapour, dried in the air, and stained with dilute carbol fuchsin.

General Morphology and Biology.

As a result of these studies, it was found possible to divide the actinomycetes into two main groups, essentially agreeing with Ørskov's division; in one of them, two subgroups could be distinguished:

I. Spores are formed in an aerial mycelium.
 A. Substratum mycelium remains undivided.
 B. Substratum mycelium divides into a kind of "fragmentation spores".
II. No spores are formed in the aerial mycelium. Substratum mycelium divides usually into more or less bacteria-like elements.

Group I A is identical with Ørskov's Group I. The characteristic feature of these organisms is the following course of development: when transferred to a suitable medium, the aerial spores germinate with the production of a filament, usually about 0·4–0·6 μ thick, which rapidly forms monopodial branches and develops into an extensive mycelium, which forms a colony of a characteristic firm and cartilaginous consistence. The mycelium remains nonseptate and coherent even in very old cultures—months and even years—falling to pieces only as a result of local processes of degeneration in the hyphae (Foulerton and Jones, 1902; Ørskov, 1923), which usually retain their uniform thickness. Only in a single one of the species of this group studied here is there a tendency to formation of peculiar swollen cells in some media (Pl. xix, fig. 2). A few words should here be said on the mode of formation of the mycelial branches. In all the actinomycetes, of this as well as of the two other groups, we see the first beginnings of the branches arise as quite small, slightly oblong or pear-shaped external buds, attached to the main stem by very thin stalks. The bud generally grows and stretches out into a long hyphal branch, which for a considerable time may be separated from the main stem by a basal constriction (Pl. xix, figs. 1, 3, 8; Pl. xx, figs. 18, 22). This phenomenon, which has been commented upon by comparatively few authors (e.g. Goadby, 1903, and Fennel, 1918), may possibly have something to do with the alleged existence of filterable forms in actinomycetes (Leyton and Leyton, 1916; Lucksch, 1930). The initial buds are sometimes, for instance, in the organisms of Group I B in liquid media, so small as to come near to the limit of visibility, and it is not inconceivable that they may be small enough to pass through bacterial filters, if they are torn loose from the cells that produce them.

After the formation of this "vegetative" or "substratum" mycelium, follows sooner or later a formation of aerial mycelium, where the growth is in contact with the air. The aerial hyphae, which are at first visible as small refractive

granules outside the vegetative hyphae, are constantly thicker than these, of very variable length, and more or less branched. The end branches are often coiled into more or less regular spirals and sometimes situated in crown- or whirl-like arrangements. The abundance of the aerial mycelium varies greatly both with the organism and the medium. In rich media, e.g. nutrient agar, it is often altogether absent, and in some strains it is very scant in all media, though always present in some medium or other, especially such as allow only a limited growth (cf. Waksman, 1919, and Ørskov, 1923). After some time, the end branches of the aerial hyphae divide basipetally into regular-sized elements, spherical to elliptical, or in some cases cylindrical. When seen under a high-power dry lens, the aerial hyphae exhibit a characteristic beaded appearance, due to small opposite incisions in the cell walls, connected by fine transversal lines. In stained preparations these lines appear as unstained intervals separating the elements into which the contents of the hyphae have divided. These unstainable intervals may even be seen before any external changes in the hypha have taken place; it seems thus, that the protoplasm separates without any formation of primary transversal walls, as contended by Ørskov (1923) and most other authors on this subject. It has not been found possible to decide whether there is actually a formation of primary septa, which afterwards split in halves, in favour of which Drechsler (1919) has brought forth strong evidence. The elements, into which the aerial hyphae divide, represent spores of the organisms, as the term "spores" is defined by Ørskov (1923): "Bodies that are identical to one another in form, which have a special mode of formation, and are distinguished by a greater power of resistance than the mycelial filaments, and which, under adequate conditions, grow out into a new mycelium". It is important to realize that they are spores in the mycological sense of the word, viz., reproductive bodies, and that they have nothing to do with the endospores of certain bacteria (the genera *Bacillus* and *Clostridium*). Numerous authors have pointed out that the aerial spores of the actinomycetes possess a somewhat higher thermoresistance than the vegetative mycelium. This was also found to be the case here. While the vegetative mycelia were usually killed in 2-5 minutes at 60° C., the spores would generally survive for 10 minutes at 60° C. or 2-5 minutes at 70° C.

This group comprises the great majority of soil actinomycetes. Hereto belong all the organisms described by Krainsky (1914), Waksman and Curtis (1916), Waksman (1919), Drechsler (1919), Millard and Burr (1926),* and further *Act. pheochromogenus* Conn (1919), *Act. cloacae* Brussoff (1920), and the organisms described by the present author in two earlier papers (Jensen, 1928, 1930*b*). On the other hand, the group comprises apparently very few animal pathogens. The only unquestionably pathogenic species seems to be *Act. madurae* (Vincent, 1894; Ørskov, 1923). The classical *Act. hominis* Bostroem (1890), as well as forms isolated by Henrici and Gardner (1921) and Grubauer (1925), do certainly belong to this group, but their pathogenicity seems somewhat doubtful.

Group I B.—This group resembles the previous one perfectly with regard to the formation of aerial mycelium and the mode of spore formation herein (Pl. xix, figs. 6, 7), but differs from it in a characteristic process of division of the vegetative hyphae, giving rise to bodies of somewhat varying appearance, but often similar to the aerial spores. This phenomenon does not appear in the same fashion in all

* With the possible exception of two species, *Act. maculans* and *Act. salmonicolor*, which might seem to belong to other groups.

strains or in all media. On nutrient agar the hyphae show, after a few days' growth, a number of fine transversal lines, appearing as unstainable intervals in stained preparations, and separating the hyphae into rod-shaped bodies of somewhat unequal size (Pl. xix, fig. 8). In some cases these bodies remain at a stage resembling diphtheroid rods (Pl. xix, figs. 11, 12), in others they are very nearly coccoid. Sometimes they resemble the somewhat mysterious objects which Lieske (1921) describes under the name of "four-hyphae-spores" (Vierhyphensporen). Similar forms arise in broth and dextrose-asparagin-solution and on potato, in which latter medium one strain (6 VI) produces fairly large (1·2–1·5 μ), roughly globular bodies, apparently arising by lateral budding from the hyphae (Pl. xix, fig. 10); this represents probably a modification of the normal lateral branches as described above under Group I A. When these globular to rod-shaped bodies are transferred to a suitable medium (dextrose or casein agar, sometimes potato extract agar) they produce a largely undivided vegetative mycelium and an aerial mycelium with spores as in Group I A (Pl. xix, figs. 6, 7). Besides this, one particular strain (6 VI) produces in acid dextrose-NH_4Cl-solution an abundance of big, globular bodies, arising by division and subsequent swelling of the hyphae (Pl. xix, fig. 9). When transferred to fresh media, these bodies have regularly failed to show any further development. Although they look like what have been described as "gonidangia" in numerous bacteria it might, in view of their apparent incapacity of growth, seem likely that they are really "involution forms" in the true sense of this much-misused term: aberrant cell types arising under subversive conditions of growth (in this case, where the growth has been checked through acidification of the medium) and devoid of any capacity of further development.

These observations throw an interesting light on a phenomenon which has caused a good deal of controversy, namely, the so-called "fragmentation spores" or "oidiospores" of the actinomycetes. A phenomenon termed "fragmentation" was first described by Boström (1890) in his *Act. hominis*, but later explained by Sauvageau and Radais (1892) as an artefact due to uneven staining of the hyphae. Lachner-Sandoval (1898) distinguished between "segmentation", i.e. spore formation in the aerial hyphae, and "fragmentation", i.e. division of the vegetative hyphae into pieces of more uneven length. Neukirch (1902) added a third kind of "spores", called "oidiospores", said to be produced by formation of primary transversal walls in the vegetative hyphae. These phenomena have been little studied in recent time, and the interpretation of the earlier records is often difficult, as pointed out by Ørskov, since there is no discrimination between the present Group I and the subsequent Group II, in which division of the vegetative hyphae is a prominent feature. Brussoff (1919) explained the fragmentation in the same manner as Sauvageau and Radais, namely, as due to the presence of deeply staining granules of volutin in the hyphae; the only organism studied was a typical representative of Group I A. Lieske (1921) describes and figures "oidiospores" in the sense of Neukirch, but the strain in question seems to be one of Group II. Foulerton and Jones (1902) describe a process of "fragmentation" of the vegetative hyphae of actinomycetes which formed spores in the aerial mycelium; here, however, it seems to be a case of local degeneration in the hyphae, as described by Ørskov (1923) in organisms of Group I. Still, even when we allow for these two sources of error—failure to distinguish between the Groups I and II, and the phenomena of degeneration—there remains a phenomenon which resembles the spore formation in the aerial mycelium, namely, the division of the vegetative hyphae into short rods and cocci of fairly regular size and shape, such

as we meet it in the organisms which we have here classified as Group I B. One of the organisms studied by Ørskov (1923) and included by him in his Group I, although with reservation, viz., *Act. Affanassiew*, behaved similarly; indeed, his figure of this organism resembles perfectly our Fig. 13, Pl. xix.

Organisms of this group seem to be comparatively rare. In the present study, only three strains were found. There are not many records in the literature of organisms which can be recognized as belonging hereto, except *Act. Affanassiew* referred to above. The "*Streptothrix*" *bucoalis* described by Goadby (1903) and an organism studied by Bachmann (1922) are certainly of this type, and the same seems to be true of a thermophilic actinomyces studied by Sames (1900) and one of the thermophilic actinomycetes studied by Schütze (1908).

Besides the outstanding morphological character of spore formation in the aerial mycelium, the organisms of Groups I A and I B have a number of biological features in common, which distinguish them from Group II. All of them liquefy gelatin, although with widely varying rapidity, as also pointed out by Waksman (1919) and Ørskov (1923). Further, they are all capable of exerting diastatic action on starch, as previously noted by Waksman (1919); the only organism studied by him, which did not liquefy gelatin or hydrolyze starch (*Act. asteroides*) belongs to Group II.* Several organisms of this group produce a characteristic brown pigment in protein media and a black pigment on potato, and not a few of them are capable of decomposing cellulose.

Group II corresponds to Ørskov's Groups II A and II B. The course of development is as follows: initially a more or less extensive vegetative mycelium is formed, consisting of hyphae similar to those in Group I. Sooner or later the vegetative hyphae divide into segments of rather varying size and shape, sometimes swollen and irregular, but usually resembling mycobacteria or corynebacteria; the process of segmentation often goes so far as to produce quite coccus-like forms. After these bacteria-like elements have been formed by division of the initial mycelia, they continue to multiply in the manner characteristic of the mycobacteria and corynebacteria, which Ørskov (1923) describes as "angular growth". This development is, however, subject to very great variations, depending both on the organisms and the medium. In some cases, e.g. the *Proact. flavescens* described below, the angular growth is hardly noticeable; the mycelia seem to remain at the stage of septation, as in Group I B, and even seem to remain undivided in some media. In another organism, described in detail in an earlier paper (Jensen, 1931*a*), variants arise with a constantly undivided vegetative mycelium as in Group I A. Finally, in the *Proact. paraffinae* described below we do not find any angular growth, but a division of the hyphae into round to oval bodies, thicker than the undivided filaments and resembling the aerial spores of Group I. An aerial mycelium is generally formed at an early stage of the growth; its hyphae are generally simpler, shorter and less branched than those of Group I, and never forming spirals. As Ørskov points out, the aerial hyphae are of the same thickness as those of the vegetative mycelium, and a differentiation into spores, as in Group I, does not take place here. In stained preparations, or when a coverslip is placed upon the growth, the aerial hyphae fall apart into generally rod-shaped fragments of variable length, and they do not show any higher

* Non-diastatic organisms of Group I may occur, such as certain organisms described by Henrici and Gardner (1921) and Millard and Burr (1926), but they are decidedly exceptional.

thermoresistance than the vegetative hyphae. It is undoubtedly this distinctive character of presence or absence of spore formation in the aerial mycelium, which should be considered the most important criterion for the distinction between Groups I and II, rather than (as Ørskov thinks) the division of the vegetative mycelium, which is subject to such wide variation, and which also occurs in Group I B. Ørskov's distinction between his groups II A and II B was based on the formation of aerial mycelium in Group II A and absence of this, in addition to a marked tendency to angular growth, in Group *II B*, but he is right in admitting that this difference is not very profound, since the property of forming aerial mycelium seems easily to be lost. *Act. farcinicus* and *Act. polychromogenes*, which Ørskov found without aerial mycelium, did apparently form this at the time of their first isolations (Nocard, 1888; Vallée, 1903). All the present organisms of Group II, except one, produced more or less aerial mycelium, although sometimes visible only under the microscope.

Besides these morphological characters, the organisms of Group II differ from Group I in other ways. In distinction from Group I, many of them are incapable of liquefying gelatin or hydrolyzing starch. On the other hand, most of them are capable of utilizing paraffin, which few of Group I can do. None of them is capable of decomposing cellulose, and they do not form any brown pigment in protein media or black pigment on potato. Finally, some of the forms studied here are acid-fast, like numerous pathogenic actinomycetes (*Act. asteroides, farcinicus, caprae*, and others) of this group. The statement of Ørskov (1923), that the organisms of Group II always produce an early surface growth in liquid media, could not be confirmed in all cases.

As will be seen from the above, and, as Ørskov points out, this group is a good deal more heterogeneous than Group I. The *Proact. flavescens* described below comes rather close to Group I both in morphological and biological respect; *Proact. agrestis*, on the other hand, shows the closest possible approximation to the mycobacteria: its initial mycelia are very small (Pl. xx, fig. 17), it assumes rapidly an entirely bacterium-like appearance (Pl. xx, fig. 19), it produces a kind of "smooth" and "rough" variant like many bacteria, and it produces an actual turbidity in liquid media, which the actinomycetes are supposed never to do. Indeed, this organism was first described as *Mycobacterium agreste* by Gray and Thornton (1928). As a matter of fact, a sharp line of distinction has never been drawn between *Actinomyces* on one side and *Mycobacterium* and *Corynebacterium* on the other. Acid-fastness occurs among actinomycetes as well as among mycobacteria, and serological reactions have failed to give any distinct separation (Fritsche, 1908; Claypole, 1913). On the morphological side, the sometimes quite profuse branching in mycobacteria and corynebacteria and the slightly accentuated mycelial character of such forms as *Act. farcinicus* and the anaerobic pathogenic actinomycetes (the Wolff-Israel-type) tend to obscure the limit. Ørskov (1923) is of the opinion that the corynebacteria and mycobacteria should really be included in Group II of the actinomycetes, because their manner of cell division (angular growth) is exactly the same. It would seem, however, that a certain distinction can be made. As Haag (1927) points out, the cell division begins in the mycobacteria and corynebacteria at so early a stage that a small mycelium is only occasionally formed (cf. the studies of Miehe (1909) on *Myc. tuberculosis* and of Ørskov (1923) on *Myc. phlei*). It is therefore suggested that the constant formation of an initial mycelium be regarded as a criterion for distinguishing the actinomycetes of Group II from the mycobacteria and corynebacteria. On the

basis of this we must regard *Proact. agrestis*, which constantly forms a small initial mycelium, as belonging to the actinomycetes, whereas for instance *Myc. coeliacum* (Gray and Thornton, 1928), which forms a small mycelium only occasionally (Jensen, 1931*b*) should remain in the genus *Mycobacterium*.

This group includes only few soil organisms. The organism described by Beijerinck as *Bac. oligocarbophilus* has been shown by Lantsch (1922) and Kober (1929) to be an actinomycete, undoubtedly belonging to Group II. Several others have been described as mycobacteria; this is true of at least two of the phenol-decomposing organisms described by Gray and Thornton (*Myc. agreste* and *Myc. actinomorphum*, as shown below) and probably also, as pointed out by Haag (1927), of the organisms studied by Vierling (1921). Beijerinck (1914) described a soil organism to which he gave the name *Actinococcus cyaneus*; his description and figures leave no doubt that it is an organism closely related to *Proact. agrestis* (see below). The generic name *Actinococcus*, however, is invalid (Buchanan, 1925). On the other hand, the group includes such typically pathogenic forms as *Act. farcinicus* and *Act. asteroides* (Ørskov, 1923). Besides this, a survey of the medical literature shows a large number of cases where organisms which seem to belong to this type, have been isolated from actinomycotic affections in man and animals. It is, however, in most cases difficult to see whether the organisms really belong to Group II or to Group I B, because they have usually only been cultivated and studied in complex organic media (nutrient agar, potato, broth, gelatin, serum, etc.), and Group I B will usually only show its characteristic spore formation in synthetic media. The anaerobic or microaerophilic, short-hyphed actinomycetes most commonly encountered in cases of actinomycosis (Wolff and Israel, 1890; Wright, 1905; Harbitz and Grøndahl, 1911; Dresel, 1915; Lieske, 1921; Magnusson, 1928, and others) demand a special interest. Ørskov (1923) studied an organism of this type and found it belonging to Group II. There is no proof, however, that this is true of all organisms of this type, since organisms of Group I B may also be concerned. Gasperini (1895) mentions that *Act. bovis*, an organism of Group I, may produce "fragmentation spores" by growth under reduced oxygen tension and Morelli (1930) claims to have changed long-hyphed, aerobic actinomycetes into organisms of the Wolff-Israel type by gradual adaptation to anaerobic conditions. In agreement herewith it was found in the present case, that *Act. albus* and *Act. californicus*, when grown on nutrient agar under reduced oxygen tension (in tubes in air-tight connection with cultures of a rapidly growing, aerobic soil mycobacterium), produced a vegetative mycelium in the condensation water, which showed a tendency to break up into rather short, rod-shaped pieces similar to Group I B. It might thus seem that there is no sharp distinction between Groups I A and I B, and that the short-hyphed, anaerobic, pathogenic actinomycetes may belong to Group I as well as to Group II. Mertens (1903) and Lieske (1921) observed a gradual change of anaerobic, short-hyphed forms into aerobic, long-hyphed ones, wherein Lieske seeks an explanation for the apparent contradiction between the results of Boström (1890) and Wolff and Israel (1891). These may also be cases of changes between Groups I A and I B, and it has in no instance been proved that Group I may change into Group II, or vice versa.

A Suggestion for Classification of the Order Actinomycetales.

It would doubtless be right, as Ørskov (1923) proposes, to regard Groups I and II as two distinct genera, since there is admittedly a very wide difference

between the quite fungus-like organisms of Group I A and the most bacterium-like forms of Group II, but his nomenclature is, as previously pointed out, less fortunate. In the present writer's opinion it would be better to reserve the name *Actinomyces* for Group I, since the first adequately described organism of this group was *Act. hominis* Boström (1890). For Group II one might suggest the name *Proactinomyces*, to be included in the family Proactinomycetaceae (Lehmann and Neumann, 1927). We can now construct the following modification of Lehmann and Neumann's classification of the order Actinomycetales:

A. No spores are formed .... Family Proactinomycetaceae.
- I. No mycelium is formed.
  - *a.* Acid-fast organisms* .... Genus *Mycobacterium.*
  - *b.* Non-acid-fast organisms* .... Genus *Corynebacterium.*
- II. Mycelium is formed .... Genus *Proactinomyces.*

B. Spores are formed .... Family Actinomycetaceae.
- I. Spores in aerial mycelium .... Genus *Actinomyces.*
- II. Spores terminally on branches of vegetative mycelium .... Genus *Micromonospora.*

The genus *Mycoplana* Gray and Thornton (1928) may possibly be placed as a genus parallel to *Mycobacterium* and *Corynebacterium.*

As we have repeatedly pointed out, the transitions between all these genera and families are quite gradual, so that we find a continuous sequence leading from the mycobacteria and corynebacteria to the most highly differentiated, entirely mould-like forms of *Actinomyces*, Group A (*Act. viridochromogenus*, *Act. reticuli*, etc.). While thus the evidence of connection with the "true" bacteria is very complete, there seems to be no connection with any genus of the Eumycetes. We must, therefore, regard the genus *Actinomyces* as a highly developed and specialized form of bacteria (cf. Lantsch, 1922), and it is not justified to speak of the actinomycetes as "a connecting link between bacteria and fungi", at least if we attach any suggestion of a phylogenetic relationship to this phrase.

Description of various Groups of Soil Actinomycetes.

Owing to the marked variability and the abundance of transition forms in the actinomycetes, the term "species" is in the following used in the sense of Waksman's "species groups", i.e. broad groups of strains agreeing in certain outstanding morphological and biological features. The opposite practice, adopted by Millard and Burr (1926), of establishing species differentiations on the basis of every observed constant difference, is certainly logical, but hardly practicable, since nearly every strain of actinomycetes isolated from a plating from an ordinary soil could then be raised to the rank of species.

Genus ACTINOMYCES, Group A.

ACTINOMYCES ALBUS (?) Krainsky (1914).

Three strains. *Hab.*—Soils 130, 163, G.—They seem to agree better with the description of Krainsky than with that of Waksman (1919). A fourth strain differed from them mainly in the formation of a pink pigment in most media.

Morphology.—The vegetative mycelium is of the usual type. The aerial mycelium consists of long, tangled, not very much branched hyphae, 0·4–0·5 μ

* This conventional way of distinguishing between *Mycobacterium* and *Corynebacterium* will probably on closer study be found to require some revision (cf. Gray and Thornton, 1928, and Jensen, 1931*b*).

thick, appearing homogeneous and undivided when examined in undisturbed condition. Only in strain G do a few hyphae on dextrose agar show the characteristic beaded appearance which accompanies the spore formation in *Actinomyces*. When mounted in water or studied in impression preparations, the aerial hyphae fall apart into rod-shaped pieces of the same thickness as the aerial hyphae, and of somewhat variable length, 0·4–0·5 × 2–4 μ, with a tendency to bipolar staining (Pl. xix, fig. 5). In strain G, some of these rods are thicker (0·7–0·8 μ) than the undivided filaments. The mode of spore formation is similar to that described by Drechsler (1919) for his strain XIII. It is also of interest to note that Ørskov (1923) mentions that the typical spore formation is difficult to detect in actinomycetes with cylindrical spores, e.g. "*Leptothrix*" *buccalis*. Only in strain G did the spores show a higher thermoresistance than the vegetative hyphae. We must, therefore, since the spore formation is so little typical, regard this species-group as situated at that end of the whole group I A, which shows the closest approximation to Group II (*Proactinomyces*).

Cultural characters.—Saccharose agar: Fair growth, becoming abundant; vegetative mycelium flat, spreading, becoming raised, first cream-coloured, later light ochre-yellow. Aerial mycelium abundant, smooth, cottony, pure white. Pale-yellow soluble pigment. Dextrose agar: Excellent growth, much resembling the previous. Nutrient agar: Excellent growth. Vegetative mycelium raised and wrinkled, with cracking surface, cream-coloured to straw-yellow. Aerial mycelium rather scant, white. Potato: Fair growth. Vegetative mycelium raised and wrinkled, cracking, dirty cream-coloured. Traces of white aerial mycelium.

ACTINOMYCES AUREUS (?) Waksman and Curtis (Waksman, 1919).

Two strains. *Hab.*—Soils 163 and 176.

Morphology.—Aerial mycelium consists of long, tangled and branching hyphae; spirals not very numerous, short, sinistrorse. Spores nearly spherical, 1·0–1·2 μ.

Cultural characters.—Saccharose agar: Growth scant in one strain, good in one. Vegetative mycelium spreading, white. Aerial mycelium first scant, white, later abundant, crusty, greyish-brown with white edges. Dextrose agar: Fair to good growth. Vegetative mycelium raised, superficial, first cream-coloured, later deep-orange. Aerial mycelium well developed, dusty, first white, later greyish-brown. Nutrient agar: Excellent growth. Vegetative mycelium superficial, wrinkled, yellowish-grey. Aerial mycelium absent or traces of white. Deep-brown pigment. Potato: Vegetative mycelium raised, spreading, yellowish-grey, becoming nearly black. Traces of white aerial mycelium. Black pigment.

ACTINOMYCES BOBILI Waksman and Curtis (Waksman, 1919).

One strain. *Hab.*—Soil 92.

This strain corresponds in most points to Waksman's description, although its aerial mycelium on saccharose and dextrose agar seems less scanty, and a heavy, brownish-black growth is produced on potato.

ACTINOMYCES CALIFORNICUS Waksman and Curtis (Waksman, 1919).

One strain. *Hab.*—Soil 92. Another, less typical strain, probably belonging to the same group, was isolated from soil 163. Strain 92 agrees very well with Waksman's description.

ACTINOMYCES EXFOLIATUS Waksman and Curtis (Waksman, 1919).

Two strains. *Hab.*—Soil 176. Both strains correspond fairly well to Waksman's description. The colours are generally darker, and the initially white aerial mycelium on saccharose agar assumes in older cultures a rose-brown colour. Waksman states that the tendency of the growth on saccharose agar to crack and peel off, from which the specific name is derived, is easily lost; with the present strains it was not noticeable at all.

ACTINOMYCES FLAVUS (?) Krainsky emend. Waksman and Curtis (Waksman, 1919).

Four strains. *Hab.*—Soils 163 and 176.

Morphology.—Aerial hyphae long, tangled, with none or a few short spirals. Spores long oval, $0{\cdot}8\text{–}1{\cdot}0 \times 1{\cdot}0\text{–}1{\cdot}5\ \mu$.

Cultural characters.—Saccharose agar: Fair to good growth, one strain very scant. Vegetative mycelium heavy, superficially spreading, first white to cream-coloured, later ochre-yellow. Aerial mycelium thin, white to yellowish-grey, absent in one strain. Dextrose agar: Good growth. Vegetative mycelium heavy, superficially spreading, ochre-yellow. Aerial mycelium thin, in patches yellowish-white to ash-grey. Nutrient agar: Excellent growth. Vegetative mycelium raised, wrinkled, yellowish-brown. Aerial mycelium absent or trace of white. Brown pigment. Potato: Good growth. Vegetative mycelium raised, lichnoid, yellowish-brown to greenish-olive. Black pigment.

ACTINOMYCES FULVISSIMUS Jensen (*1930b*).

Two strains. *Hab.*—Soil AII, and acid sand soil from Cooper Park. The strains generally agree with the author's previous description, but the golden pigment is less typical in saccharose agar, and the aerial mycelium more abundant and pure grey on dextrose agar.

This species is probably identical with *Act. flavus* Millard and Burr (1926); this name, however, is obviously invalid, since this organism is well distinguished from the one to which Krainsky previously (1914) had given the name *Act. flavus* (see above).

ACTINOMYCES GRISEUS Krainsky emend. Waksman and Curtis (Waksman, 1919).

One strain. *Hab.*—Soil U. It agrees well with Waksman's description, from which it differs only in producing a lemon-yellow soluble pigment in nearly all media. *Act. griseus* is one of the most easily recognized species of actinomyces, as well as one of the most well-defined, as can be seen from the closely tallying descriptions by Waksman (1919), Fellers (1922), and the present author (Jensen, 1930*b*).

ACTINOMYCES 218, Waksman (1919).

One strain. *Hab.*—Soil 6. This strain corresponds almost perfectly to Waksman's description of his strain 218, which seems to be a "chromogenic" parallel to *Act. griseus*, from which it differs only in producing a brown pigment in protein media and in being less strongly proteolytic.

ACTINOMYCES HYGROSCOPICUS, n. sp.

Seven strains. *Hab.*—Soils 92, 163, and 176.

Morphology.—Vegetative mycelium of the usual type; the hyphae are rather stout, $0{\cdot}6\text{–}0{\cdot}8\ \mu$ thick. Aerial hyphae long, tangled, richly branched, $0{\cdot}8\text{–}1{\cdot}0\ \mu$

thick; spirals are numerous, sinistrorse, narrow, sometimes long, but mostly quite short, only 1–2 turns, closed, typically situated as dense clusters on the main stems of the aerial hyphae. Spores oval, 0·8–1·0 × 1·0–1·2 μ.

Cultural characters.—It is a striking feature in this species-group, that the aerial mycelium, which in other actinomycetes is strikingly hydrophobic, does here in cultures on certain media—dextrose or glycerin asparagin agar—become moistened and exhibits dark, glistening patches which, when touched with the needle, prove to be a moist, smeary mass of spores. This characteristic feature is not equally distinct in all strains.

Saccharose agar: Good to abundant growth. Vegetative mycelium heavy, superficially spreading, folded, glossy surface, first white to cream-coloured, later sulphur-yellow to yellowish-grey, with golden to light-orange reverse. Soluble pigment of the same colour. Aerial mycelium scant, thin, white, or altogether absent. Dextrose agar: Good growth. Vegetative mycelium superficially spreading, surface granulated, first cream-coloured to straw-yellow, later dull chrome-yellow to brownish-orange. Aerial mycelium thin, smooth, dusty, white to pale yellowish-grey, after 1–2 weeks more or less abundantly interspersed with small, moist, dark violet-grey to brownish patches which gradually spread over the whole surface. Light-yellow soluble pigment. Nutrient agar: Good growth. Vegetative mycelium raised, wrinkled, glossy, first cream-coloured, later yellowish-grey with yellowish-brown reverse. Aerial mycelium mostly absent, sometimes scant white. Potato: Fair growth. Vegetative mycelium raised, wrinkled, first cream-coloured, later yellowish-grey to dull-brownish. Aerial mycelium absent or trace of white.

Biochemical features.—Saccharose is inverted. Nitrate is not reduced with saccharose as source of energy. Starch is hydrolyzed. Cellulose is decomposed readily by some strains. Gelatin is slowly liquefied without any pigment formation. Milk is completely digested in 3–4 weeks at 30° C., without any previous coagulation: the reaction becomes faintly acid (pH about or below 6·0).

ACTINOMYCES MICROFLAVUS (?) Krainsky (1914).

One strain. *Hab.*—Soil 176.

Morphology.—Aerial mycelium consists of tufts of short, straight hyphae, not much branched, no spirals. Spores oval, 1·0–1·2 × 1·2–1·5 μ.

Cultural characters.—Saccharose agar: Very scant growth. Vegetative mycelium spreading widely into the medium, thin, colourless. Aerial mycelium thin, pale reddish-brown. Dextrose agar: Scant growth. Vegetative mycelium forms isolated colonies, first colourless, becoming deep ochre-yellow. Aerial mycelium thin, yellowish-grey with rose spots. Nutrient agar: Fair growth. Vegetative mycelium flat, growing down, cream-coloured, central part raised, folded, ochre-yellow. Aerial mycelium thin, white, limited to the flat part of the growth. Potato: Slow, but eventually good growth of a very characteristic appearance. Vegetative mycelium first flat, spreading into medium, yellowish with white edges. After 10–15 days the central part appears raised, folded, mulberry-like, pure ochre-yellow. Trace of white aerial mycelium.

ACTINOMYCES PARVUS (?) Krainsky (1914).

Three strains. *Hab.*—Soils 125, 176, and U. Otherwise of very common occurrence in Australian soils.

Morphology.—Vegetative mycelium of strain U shows in culture on nutrient agar a tendency to formation of remarkable, big, globular to pear-shaped bodies

(Pl. xix, fig. 2). Aerial hyphae fairly short, straight, with little branching. Spores oval, 0·8–1·0 × 1·0–1·2 μ.

Cultural characters.—Saccharose agar: Scant growth. Vegetative mycelium flat, growing down, first colourless, later straw-yellow. Aerial mycelium absent or thin white veil. Dextrose agar: Scant growth. Vegetative mycelium slightly raised, wrinkled, sulphur-yellow to honey-yellow. Aerial mycelium absent or trace of white. Nutrient agar: Fair growth. Vegetative mycelium raised, lichnoid, first honey-yellow, later rust-brown, of a somewhat soft consistence. No aerial mycelium. Potato: Scant growth. Vegetative mycelium raised, much wrinkled, first cream-coloured, later dirty honey-yellow to olive-yellow. No aerial mycelium.

Krainsky states that his *Act. parvus* was strongly proteolytic. The present strains showed this property only to a slight extent.

Actinomyces reticuli Waksman and Curtis (Waksman, 1919).

Two strains. *Hab.*—Soil 176. Waksman states that strains of this species may vary widely in their cultural characters. The present strains agreed with Waksman's description in the peculiar structure of the aerial mycelium, although they differed in several other respects.

Morphology.—Aerial mycelium consists of long, richly branching hyphae, 0·8–1·0 μ thick. The branches are arranged in definite whirls, but terminate in short, sinistrorse spirals, unlike the organism described by Waksman. Spores are oval, 0·8–1·0 × 1·2–1·6 μ.

Cultural characters.—Saccharose agar: Scant growth. Vegetative mycelium thin, spreading, colourless. Aerial mycelium thin, smooth, slate-grey. Dextrose agar: Good growth. Vegetative mycelium flat, growing down, white. Aerial mycelium abundant, smooth, lead-grey. Nutrient agar: Good growth. Vegetative mycelium raised, wrinkled, yellowish-brown. Trace of white aerial mycelium. Deep-brown pigment. Potato: Good growth. Vegetative mycelium raised, wrinkled, greyish-black. Trace of white aerial mycelium. Black pigment.

Actinomyces roseochromogenus (Krainsky).

Synonym.—*Act. roseus* (Krainsky) emend. Waksman and Curtis (Waksman, 1919).

The use of the name *roseus* by Krainsky (1914) can hardly be regarded as valid, since it was used previously by Namyslowski (1912) for an organism which was apparently different from the one studied by Krainsky. It is, therefore, suggested to replace the specific name by *roseochromogenus.*

Morphology.—Aerial hyphae long, not very much branching, 1·0–1·2 μ thick. The branches terminate in fairly long, regular, sinistrorse spirals. Sometimes 3 to 5 branches are seen issuing together from the end-point of a main stem, thus giving a suggestion of whirl formation as in *Act. reticuli.*

Cultural characters.—Saccharose agar: Scant growth in one strain, abundant in one. Vegetative mycelium flat, spreading, colourless to white with pale-yellow reverse. Aerial mycelium abundant, smooth, pale greyish-rose. Dextrose agar: Good growth. Vegetative mycelium smooth, spreading, pale-yellow. Aerial mycelium abundant, smooth, cottony, first white, after a few days becoming rose-cinnamon, with many small white tufts. Nutrient agar: Excellent growth. Vegetative mycelium spreading, wrinkled, first yellowish-grey, later red-brown. Aerial mycelium develops late, first white, then pale rose-grey. Deep-brown pigment. Potato: Excellent growth. Vegetative mycelium spreading, roughly

granulated, yellowish-grey to greyish-black. Aerial mycelium absent or trace of white. Black pigment.

Dissociation.—By plating from the tufts of white aerial mycelium arising on dextrose agar or casein agar, a variant with pure white aerial mycelium is obtained.

ACTINOMYCES RUTGERSENSIS (?) Waksman and Curtis (Waksman, 1919).

Two strains. *Hab.*—Soils 6 and A II.

Morphologically these strains differ from the organism described by Waksman in not producing real spirals; the aerial hyphae are only curled and waved to a considerable extent. The cultural characters agree very well with those listed by Waksman.

ACTINOMYCES VERNE (?) Waksman and Curtis (Waksman, 1919).

Two strains. *Hab.*—Soils 125 and 163.

Morphology.—Aerial mycelium on dextrose agar consists of much curled and tangled hyphae, with irregular, sinistrorse spirals, 0·8–1·0 μ thick. Spores short cylindrical, 1·0 × 1·2–1·6 μ, not formed until after about three weeks; also many curved fragments, 6–10 μ long, are formed.

Cultural characters.—Saccharose agar: Good growth. Vegetative mycelium superficially spreading, slightly raised, first pale olive-yellow, later dark olive-grey to brownish-grey. No aerial mycelium. Yellowish to olive-brown soluble pigment. Dextrose agar: Good growth, similar to previous, with small tufts of whitish to greenish-grey aerial mycelium. Nutrient agar: Fair growth. Vegetative mycelium raised, wrinkled, cream-coloured to yellowish-grey. No aerial mycelium. Brown pigment in one strain. Potato: Fair growth. Vegetative mycelium wrinkled, greenish-grey to brownish-black. Trace of white aerial mycelium. Brownish pigment.

ACTINOMYCES VIRIDOCHROMOGENUS (Krainsky) emend. Waksman and Curtis.

Three strains. *Hab.*—Soils 163, 176, U. Otherwise very common in Australian soils. The present strains differ a good deal from the description by Waksman in their manner of growth on saccharose agar, but they all produce the typical blue-green aerial mycelium on some medium, especially dextrose agar. Very characteristic is also the arrangement of long, fine, regular spirals as side branches of very long, only slightly branching aerial hyphae.

Genus ACTINOMYCES, Group B.

The three strains of this group, whose general morphology has been described above, differ from each other in so many cultural characters that they cannot unreservedly be united into a single species, but on the other hand it would not seem advisable to erect three distinct species out of them on the basis of the study of so few strains.

Strain 6VI. *Hab.*—Soil 6. *Morphology.*—Vegetative hyphae on casein agar long, branching, of variable thickness, from 0·8–1·0 up to 2·5–3·0 μ. On nutrient agar and potato, transitions from long filaments to short rods (Pl. xix, fig. 12) and coccoid forms (Pl. xix, fig. 10), 1·0–1·2 × 1·2–1·5 μ. In dextrose-NH_4Cl-solution big globular forms, 2·5–3·0 μ (Pl. xix, fig. 9). Aerial hyphae on casein agar or potato extract agar, long, straight, branching, no spirals, about 1 μ thick. Spores short oval to nearly spherical, 1·0–1·2 μ (Pl. xix, fig. 6). *Cultural characters.*—

Saccharose agar: Good growth. Vegetative mycelium superficially spreading, raised, much wrinkled (lichnoid), cream-coloured, first of a loose consistence, later more firm and cartilaginous. Aerial mycelium develops slowly, as the growth becomes hard, of a dull-white colour. Dextrose agar: Good growth, rather similar to previous; aerial mycelium more abundant, cottony, pale yellowish-grey. Nutrient agar: Good growth. Soft, cream-coloured smear without aerial mycelium, first smooth, later slightly wrinkled, of entirely bacterium-like appearance. Potato: Fair growth. Flat, smooth, dirty cream-coloured, glistening smear, of a viscous and gum-like consistence. No aerial growth. Dextrose broth: Soft cream-coloured growth along edges of surface. Broth turbid when shaken.

Strain 6S. Hab.—Soil 6. *Morphology.*—Vegetative mycelium on casein agar similar to 6VI. On nutrient agar the hyphae mostly remain undivided, but in the condensation water of this medium, as well as in dextrose broth, potato, and dextrose asparagin solution, they divide into short rods (Pl. xix, fig. 8). Aerial hyphae on dextrose agar and casein agar long, tangled, without spirals, 0·8–1·0 μ thick. Spores long oval to barrel-shaped, 0·8–1·0 × 1·2–1·6 μ. *Cultural characters.*—Saccharose agar: Scant growth. Vegetative mycelium thin, deeply spreading, colourless. Aerial mycelium thin, tufted, zonate, first white, later pale pink. Dextrose agar: Vegetative mycelium raised, smooth, glistening, first cream-coloured, later ochre-yellow, surface first somewhat soft, later, when aerial mycelium develops, becoming hard. Aerial mycelium abundant, cottony, dull rose. Nutrient agar: Good growth. Vegetative mycelium raised, smooth, hard, yellowish-grey. No aerial mycelium. Pale yellowish-brown pigment. Potato: Abundant growth. Vegetative mycelium spreading, very much wrinkled, first cream-coloured, later dirty red-brown, of a soft consistence. No aerial mycelium. Yellowish-brown pigment.

Strain A III. Hab.—Soil A. *Morphology.*—Generally much like previous. On nutrient agar the hyphae divide after a few days into rather regular, oval to nearly spherical elements, 1·0–1·2 × 1·2–1·4 μ (Pl. xix, fig. 13), almost exactly reproducing Ørskov's (1923) figure of *Act. Afanassiew*. *Cultural characters.*—Saccharose agar: Fair growth. Vegetative mycelium superficial, wrinkled, glossy, first colourless, later faint brownish, firm, with a somewhat loose surface. Aerial mycelium well developed, smooth, pale ash-grey. Dextrose agar: Fair growth. Vegetative mycelium flat, pale yellowish-grey, with tufts of pale-grey aerial mycelium. Nutrient agar: Good growth. Vegetative mycelium superficial, raised, much wrinkled, cream-coloured, of a very soft consistence, entirely bacterium-like. Potato: Fair growth. Vegetative mycelium spreading, wrinkled, cream-coloured, first very soft, later becoming hard, when aerial mycelium develops. Aerial mycelium starts on tip of growth, spreads gradually downwards, pale-grey. Dextrose broth: Flaky cream-coloured sediment; broth faintly turbid.

Genus Proactinomyces.

Proactinomyces flavescens, n. sp.

Three strains. *Hab.*—Soils 129, 163, 176. This is one of the species of *Proactinomyces*, which show the closest resemblance to *Actinomyces*. Apparently it is a representative of that group of comparatively rare strains, which Lieske (1921) describes as "mittellang".

Morphology.—The vegetative mycelium varies much according to the medium. On media where a firm growth is produced it appears as long, branched, non-septate hyphae, 0·4–0·6 μ thick. In other media, e.g. nutrient agar and potato,

septation occurs, and the mycelium appears in preparations as fragments of very variable size, partly resembling highly branched mycobacteria. In several cases—for instance, on nutrient agar at 28–30° C., in 5–6 weeks old cultures in dextrose broth, and in dextrose-NH_4Cl-solution—the short elements assume swollen, fusiform to lemon-shaped forms (cf. Ørskov's (1923) description of *Act. corneae*). The aerial mycelium consists of fairly long hyphae of the same thickness as the vegetative hyphae, not very much branched, without spirals, often clinging together in wisps. A differentiation into spores is never visible by direct microscopical examination. Neither is this the case in stained preparations; here the aerial hyphae break up into fragments of quite variable length, from 1·2–1·5 up to 10–12 μ, showing an irregular, granulated staining. From this picture there is not a very wide step to that of *Act. albus*, as described above.

Cultural characters.—Saccharose agar: Good growth. Vegetative mycelium superficially spreading, much raised and wrinkled, cracking, white to cream-coloured, of a dry, but loose and crumbly consistence. Aerial mycelium scant, thin, white. Faint yellow soluble pigment after 2–3 weeks. Dextrose agar: Good growth. Vegetative mycelium superficial, wrinkled, honey-yellow to deep olive-yellow, of a hard and cartilaginous consistence. Aerial mycelium thin, smooth, white. Yellow soluble pigment. Nutrient agar: Good growth. Vegetative mycelium raised and much wrinkled, first dirty cream-coloured, later dark yellowish-grey, of a soft, moist, curd-like consistence. No aerial mycelium. No pigment. Potato: Good to excellent growth. Vegetative mycelium much raised and wrinkled, first cream-coloured, later yellowish-brown, soft and smeary. No aerial mycelium. No pigment. Dextrose broth: Rather scant growth. Granulated, yellowish sediment; no surface growth. Broth clear. No pigment. No acidity.

Biochemical features.—Saccharose is inverted. Starch is hydrolyzed. Cellulose is not decomposed. Gelatin is liquefied slowly. Nitrate is reduced slightly or not at all with various sources of energy. Milk is coagulated and slowly redissolved with acid reaction. Final reaction in dextrose-NH_4Cl-solution, pH 3·6–3·9. No growth under anaerobic conditions.

PROACTINOMYCES PARAFFINAE, n. sp.

Five strains. *Hab.*—Soils 163 and A. It appears somewhat problematic, in which genus this species-group should really be placed. Its mode of "spore" formation in the vegetative mycelium is quite like that in the aerial mycelium of *Actinomyces*, Group A. However, since it lacks the spore formation in the aerial mycelium and conforms with *Proactinomyces* in several other respects (acid-fastness, no diastatic action, no liquefaction of gelatin) it would seem more reasonable to include it in this latter genus.

Morphology.—In agar media (e.g., dextrose agar) the organism forms initially an extensive mycelium of long, richly branching hyphae, 0·4–0·5 μ thick. After 5–6 days at room temperature, numerous end branches swell to about double thickness, become more refractive, exhibit fine incisions along their external contours, and divide into oval, spore-like elements, 0·8–1·0 × 1·2–1·5 μ. This process of division starts at the tips of the swollen branches and proceeds basipetally (Pl. xx, fig. 15), until most of the hyphae appear divided. Primary septa are not seen in the hyphae even with the best optical equipment. A similar process of division takes place in liquid media, where also the filaments often fall into fragments of variable length. The spore-like elements, but not the undivided filaments, are markedly

acid-fast (Pl. xx, fig. 14). The aerial mycelium consists of rather short, straight, not very much branched hyphae, 0·4–0·6 μ thick, which never show any differentiation into spores.

Cultural characters.—Saccharose agar: Very scant growth. Thin colourless veil, sometimes with a trace of white aerial mycelium. Dextrose agar: Fair growth. Vegetative mycelium flat, growing into medium, pale ochre-yellow to orange, with raised outgrowths on the surface, of a crumbly consistence. Scant white aerial mycelium. Nutrient agar: Slow, but good growth. Vegetative mycelium superficial, somewhat raised, ochre-yellow, hard, but with a loose, smeary surface. Aerial mycelium scant, small white tufts. No pigment. Potato: Fair growth. Vegetative mycelium granulated, first pale-yellow, later deep ochre-yellow to orange. Scant white aerial mycelium. No pigment. Liquid media (milk, broth, synthetic solutions): Small round granules of various yellow to orange colours, firm, but can be crushed into a homogeneous smear. In quite old broth cultures a thick, hard, orange to brownish surface pellicle is formed.

Biochemical features.—Saccharose is not inverted. Starch is not hydrolyzed. Cellulose is not decomposed. Nitrate is not reduced. Gelatin is not liquefied. Milk is not coagulated or digested. Final reaction in dextrose-NH_4Cl-solution, pH 4·4–4·6. All strains show a marked power of utilizing paraffin wax as source of energy.

PROACTINOMYCES POLYCHROMOGENES (Vallée).

Syn. *Streptothrix polychromogenes* Vallée (1903).

This organism, which has previously been described in detail (Jensen, 1931*a*) under the name *Act. polychromogenes*, belongs quite evidently to the genus *Proactinomyces* (cf. Ørskov, 1923).

PROACTINOMYCES ACTINOMORPHUS (Gray and Thornton).

Syn. *Mycobacterium actinomorphum* Gray and Thornton (1928); *Actinomyces actinomorphus* (Gray and Thornton), Bergey (1930).

Four strains. *Hab.*—Soils A I, A II, 6, 163.

Morphology.—The organism varies considerably with the medium. In media permitting a good growth (nutrient or dextrose-asparagin-agar) there is, after 20–24 hours at 25–30° C., a formation of extensive mycelia of long, curled and richly branching hyphae, penetrating into the medium to a marked extent. Ordinary stained smear or impression preparates show only bacteria-like elements —curved and branched rods, 0·4–0·6 μ thick, of variable length (Pl. xx, fig. 20), gram-positive and non-acid-fast. Already, after two days, the mycelia divide into segments, often in angular arrangement, generally 3–6 μ long; coccoid forms are not seen. On media which allow only a poor growth (saccharose or glycerin nitrate agar or solution, water agar, etc.) the mycelial stage persists for a much longer time, and the organism appears microscopically as a typical actinomyces (Pl. xx, fig. 21–22); also here rod-shaped elements are formed in old cultures on the surface of agar media. In these meagre media, occasionally also on dextrose-agar, there is an abundant production of aerial hyphae; these are fairly straight and little branched, of the same thickness as the substratum hyphae (0·4–0·6 μ), and appear in stained preparations as rod-shaped fragments of varying length, not showing any differentiation into spores. The aerial mycelium tends to disappear after prolonged cultivation, especially in transfers from old cultures.

Cultural characters.—Saccharose agar: Fair growth. Substratum mycelium flat, thin, colourless, spreading deeply into the agar. Aerial mycelium abundant, smooth, snow-white, resembling chalk-powder. The surface growth becomes gradually wrinkled and soft. In Strain 163 the growth is very abundant, forming a thick, smooth, moist, cream-coloured smear of a soft, pasty consistence. No soluble pigment. Dextrose agar: Fair to good growth. Substratum mycelium first raised and wrinkled, white, later smooth, cream-coloured, of a very soft consistence. Smooth, snow-white aerial mycelium is formed early, but tends to disappear after 10–12 days. Nutrient agar: Good to excellent growth. Substratum mycelium forms a raised, smooth or wrinkled, soft, cream-coloured smear. No aerial mycelium. No pigment. Potato: Fair to excellent growth, forming a smooth, soft, spreading, yellowish-grey smear. No aerial mycelium or pigment. Dextrose broth: Good growth. Thick, white, soft sediment, later thin, white, fragile surface pellicle. Broth becomes turbid. No acidity. Gelatin: Filiform, cream-coloured growth along the stab. Slow, saccate liquefaction; liquefied gelatin clear, viscid, without pigment.

One of the strains of *Myc. actinomorphum* isolated by Gray and Thornton was found to agree with the present group in every respect except for failure to produce aerial mycelium on saccharose-nitrate-agar. This is perhaps not surprising in view of the much longer time it had been subjected to artificial cultivation. On dextrose-asparagine-agar some aerial mycelium was formed.

PROACTINOMYCES AGRESTIS (Gray and Thornton).

Syn. *Mycobacterium agreste* Gray and Thornton (1928); *Actinomyces agreste* (Gray and Thornton), Bergey (1930).

Five Strains. *Hab.*—Soils U, G, A I, 129, A III.

Morphology.—Cells sown on surfaces of agar grow out after 18–24 hours into small, but definite mycelia of an extent of up to 40–50 μ (Pl. xx, fig. 17). Some branches show a tendency to grow down into the agar. Septa are visible already at this stage, in the living state as well as in impression preparations (Pl. xx, fig. 16). Smear-preparations show only long branched rods, often in V- or Y-arrangement, 4–12 $\times$ 0·8–1·2 μ. The cells are gram-positive, non-acid-fast. The initial mycelia break up into long branching rods (Pl. xx, fig. 18), the ends of which sometimes show a tendency to bend and grow past each other ("slipping" growth). After 2–3 days at room temperature most of the cells in the interior of the colonies have divided into short rods and cocci, 1·2–3·0 $\times$ 0·8–1·2 μ. Round the edge of the colony one sees a number of rhizoid projections of long branched cells which remain undivided for a longer period and give a very characteristic appearance to the colonies (cf. Gray and Thornton, 1928). After 4–5 days these cells, too, have mostly divided into short rods and cocci, except the cells at the extreme tips of the projections, which still remain rod-shaped (Pl. xx, fig. 19). At higher temperatures (30–32° C.) the cells are often longer, 3–5 $\times$ 0·8–1·2 μ. In old cultures almost only the coccoid forms are seen.

Cultural characters.—Saccharose agar: Fair growth, smooth, convex, shining surface, butyrous consistence, edge entire, first cream-coloured, later pinkish to pale-greyish orange. Dextrose agar: Good growth, narrow, raised, smooth surface, finely myceloid edges, soft consistence, first white, later cream-coloured, finally pale-pink. Nutrient agar: Good growth, similar to previous, greyish-orange colour. Potato: Excellent growth, raised, restricted, finely rugose surface, dull yellowish-grey, soft. Dextrose broth: Good growth, first (two days) uniform turbidity,

later abundant cream-coloured sediment and thick fragile surface scum; no acidity. Gelatin: Filiform, white growth, with fine thread-like projections along line of stab; no liquefaction.—Distinct soluble pigments are not formed.

Dissociation.—The above description refers to the appearance of cultures as isolated from the soil. All strains showed, in platings from 2–5 months old broth cultures, a dissociation into two types of colonies: a "soft" type corresponding to the original, and a "hard" type, which produces a dry, wrinkled, firmly adherent growth in solid media, and in broth a tough surface pellicle, without any turbidity. Morphologically the two types are indistinguishable, except for the fact that the "hard" shows a rudimentary formation of aerial hyphae after 1–2 days on dextrose agar—short, straight, simple filaments, which soon disappear again. In the case of two strains (U and 129) these findings were confirmed with single-cell cultures obtained by the method of Ørskov (1922). The "hard" types have not so far reverted to the original. The whole phenomenon is apparently an analogy to the production of "plane" and "perrugose" varieties in the saprophytic mycobacteria (Haag, 1927).

The strains of this species studied by Gray and Thornton (1928) were all capable of attacking phenol and/or cresol, as a consequence of the selective method by which the cultures had been obtained. Of the present strains only two (G and U) were capable of attacking phenol; apparently this character is as variable as several other biochemical properties of this group, as shown by Gray and Thornton.

Proactinomyces minimus, n. sp.

One strain. *Hab.*—Soil from a flower pot.

Morphology.—Smear preparations from 3–4 days old agar cultures show 0·4–0·6 μ thick rods, bent and irregular, some branching or in V-position, of very variable length, from almost coccoid up to 8–10 μ long. Already after 10–12 days there are only few short rods (0·5–0·7 × 1·5–3·0 μ) left, and in older cultures (1–2 months) one sees only small cocci, 0·5–0·7 μ, mostly adhering into short chains or small clumps. The cells are gram-positive, but stain rather badly with ordinary dyes. The organism is acid-fast to a certain extent; in four-days-old cultures most cells are decolourized by the acid, although some retain the stain well; the small coccoid forms show good acid-fastness after six weeks. Direct observation on agar blocks shows a mode of development very similar to that of *Proact. agrestis*, from which the present organism differs mainly in the much smaller size of its elements, its acid-fastness, and its slower growth. There is here the same formation, after 2–3 days, of small mycelia, dividing into rods and finally cocci, and the same formation of burr-like colonies with rhizoid projections, in the tips of which the cells remain undivided for a longer time than those in the interior of the colony. Aerial growth is never observed.

Cultural characters.—The growth is most characteristic at room temperature. On potato and the agar media listed below, it is in general very slow, but ends with becoming quite abundant after 6–8 weeks; the consistence is that of a firm, crumbly paste. It is first colourless, later assuming a beautiful pink colour, most nearly corresponding to Flesh Pink (dextrose and nutrient agar) or Coral Pink (saccharose agar and potato), Rdg.* XIII. 5′ 00-R. f-d. Saccharose-nitrate-agar: Growth first thin and flat, later raised, restricted, with rugose surface and finely

* Ridgeway, Colour Standards and Nomenclature.

myceloid edges. Dextrose-asparagin-agar: Growth restricted, much raised and folded (walnut-kernel-like), with finely myceloid edges. Nutrient agar: Growth very much similar to the previous. Potato: Growth spreading, much raised, finely wrinkled (lichnoid). Dextrose-broth: Thin, broken, cream-coloured surface scum and sediment; broth clear. No acidity. Gelatin: Filiform, slightly granulated, cream-coloured growth along stab. No liquefaction.

Starch is not hydrolyzed. Cellulose is not attacked. Paraffin is utilized. No soluble pigments are formed.

Relative Abundance of Actinomyces *and* Proactinomyces *in the Soil.*

As previously mentioned, *Actinomyces* have been far more frequently found in the soil than *Proactinomyces*. This was also the case in the present work.

Table 1.
Comparative Physiology of *Actinomyces* and *Proactinomyces*.

Genus.	Organism	Diastatic Action.	Utilization of Xylan.	Utilization of Cellulose.	Liquefaction of Gelatin	Growth on Paraffin	Final pH in Dextrose-NH_4Cl-Solution.	Brown Pigment in Protein Media.
Actinomyces, Group A.	*Act. albus*	+	(+)	(+)	+	+	3·4–3·6	–
	,, *aureus*	+	+	–	+	–	3·4–3·6	+
	,, *bobili*	+	+	–	+	–	3·5–3·6	+
	,, *californicus*	+	–	–	+	–	4·5–4·7	–
	,, *exfoliatus*	+	(+)	–	+	–	4·5–4·7	–
	,, *flavus*	+	+	±	+	–	4·5–4·7	+
	,, *fulvissimus*	+	±	–	+	–	4·5–4·7	–
	,, *griseus*	+	(+)	–	+	–	4·9–5·0	–
	,, 218 W.	+	+	–	+	+	4·8–4·9	+
	,, *hygroscopicus* ..	+	±	±	+	–	3·7–3·8	–
	,, *microflavus*	+	–	–	+	–	5·1–5·2	–
	,, *parvus*	+	–	±	+	–	5·1–5·2	–
	, *reticuli*	+	–	+	+	+	4·1–4·2	+
	,, *roseochromogenus* ..	+	±	±	+	–	4·4–4·5	+
	,, *rutgersensis*	+	–	–	+	–	5·0–5·1	–
	,, *verne*	+	–	–	+	–	5·0–5·1	–
	,, *viridochromogenus* ..	+	+	(+)	+	–	5·0–5·1	+
Actinomyces, Group B.	*Act.* 6 VI	+	(+)	–	+	–	4·5–4·6	–
	,, 6 S	+	+	+	+	+	4·5–4·6	–
	,, A III	+	–	–	+	–	4·1–4·2	–
Proactinomyces.	*Proact. flavescens*	+	–	–	+	–	3·6–3·9	–
	,, *paraffinae* ..	–	(+)	–	–	+	4·4–4·6	–
	,, *polychromogenes* ..	–	–	–	–	+	4·4–4·6	–
	,, *actinomorphus* ..	+	–	–	+	+	4·9–5·1	–
	,, *agrestis*	–	–	–	–	+	4·4–4·6	–
	,, *minimus*	–	–	–	–	+	4·8–4·9	–

± indicates that the character is positive in some strains, negative in others.
(+) indicates that the character is present to a slight degree only.

While *Actinomyces*-colonies often account for 30–50% or more of the total number of colonies on plates of casein agar, it was rather exceptional to find a colony of *Proactinomyces*; it was necessary to make a special search for them in order to obtain the number of forms described above. Certain differences in the comparative physiology of the two genera might seem to offer an explanation for the relative preponderance of *Actinomyces*. As seen from Table 1, and as mentioned previously, all *Actinomyces* exert proteolytic activities (liquefy gelatin) and hydrolyze starch, many of them are capable of utilizing pentosan (Na-xylanate in mineral nutrient solution) and several of decomposing cellulose; *Proactinomyces* are generally non-proteolytic and non-diastatic, do not as a rule attack xylan, are always incapable of decomposing cellulose, but typically capable of utilizing paraffin.* It would, therefore, seem likely that the *Actinomyces* are better able to live on plant residues in the soil than the *Proactinomyces*. The table further shows that the resistance to acidity, which is quite characteristic for the strains within each single species-group (Jensen, 1930*b*), does not allow any distinction between *Actinomyces* and *Proactinomyces*.

A soil from a flower bed (heavy loam, rich in organic matter) gave, by plating in a dilution of 1:200,000 on 5 parallel plates of casein agar, 73 colonies of actinomycetes; 2 of these proved to be *Proactinomyces*; 1% of paraffin wax was added, and the moist soil was incubated for 1 month at room temperature, after which time a plating in a dilution of 1:500,000 on 5 parallel plates gave 303 colonies of actinomycetes, 30 of which proved to be *Proactinomyces* (*polychromogenes, agrestis*, and *paraffinae*). There is thus here a considerable increase, both absolutely and relatively, in the abundance of *Proactinomyces*, a result which indicates that these organisms may under special circumstances become important agents in the decomposition processes in the soil.

Summary.

A study was carried out on the morphology and biology of a number of strains of actinomycetes from Australian soils. They proved to fall into two main groups (apart from the genus *Micromonospora*), broadly corresponding to a division previously suggested by Ørskov.

I. Organisms producing an aerial mycelium which differentiates into spore-like bodies. Two subgroups could be distinguished: one in which the vegetative mycelium remains undivided, and one in which it divides into a kind of "fragmentation spores". The latter subgroup is of rare occurrence, and it is not certain that the two subgroups are sharply distinguished. All organisms of this group liquefy gelatin and hydrolyze starch, and several of them are capable of decomposing xylan and cellulose. Those actinomycetes which produce a characteristic brown pigment in protein media belong to this group, which includes the large majority of soil actinomycetes. It is suggested to reserve the generic name *Actinomyces* for this group. Seventeen species, among which one is new (*Act. hygroscopicus*), are described.

II. Organisms producing an aerial mycelium (sometimes nearly or wholly absent) without any differentiation into spores. The vegetative mycelium divides

* In a previous paper (Jensen, 1931*a*) it was erroneously stated that *Proact. polychromogenes* does not attack paraffin; this is, however, the case when it is grown in mineral nutrient solution with flakes of paraffin and not, as was previously done, on agar with addition of paraffin.

generally into bacteria-like segments which multiply in the same manner as the mycobacteria and corynebacteria, to which the transition from this group is very gradual. It is suggested that the formation of an initial mycelium be used as a criterion for the distinction of this group from the genera *Mycobacterium* and *Corynebacterium*. Organisms of this group often do not liquefy gelatin or hydrolyze starch and are always incapable of decomposing cellulose, but generally are capable of utilizing paraffin; several of them are acid-fast. These organisms are of rare occurrence in the soil; their abundance here can be increased by addition of paraffin to the soil. Many pathogenic actinomycetes belong to this group. It is suggested to classify this group as a separate genus, *Proactinomyces*, n. gen., to be included in the family Proactinomycetaceae Lehmann and Neumann. Six species are described; among these three are new (*Proact. flavescens*, *paraffinae*, and *minimus*). The order Actinomycetales can then be divided into the families Proactinomycetaceae (*Corynebacterium*, *Mycobacterium* and *Proactinomyces*) and Actinomycetaceae (*Actinomyces* and *Micromonospora*).

The sequence from *Actinomyces* to *Corynebacterium* and hence to "true" bacteria is very complete, and there is no reason to place the actinomycetes among the *Fungi imperfecti*.

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EXPLANATION OF PLATES XIX-XX.

Plate xix.

Fig. 1.—*Act. viridochromogenus.* Vegetative mycelium. Dextrose asparagin solution, 2 d. 28° C.—Fig. 2. *Act. parvus.* Vegetative mycelium. Nutrient agar, 16 d. 30° C.—Fig. 3. *Act.* 6 S. Vegetative mycelium. Condensation water of dextrose casein agar, 1 d. 30° C.—Fig. 4. *Act.* 218 Waksman. Aerial mycelium. Saccharose agar, 5 d. room tpt.—Fig. 5. *Act. albus.* Aerial mycelium. Dextrose agar, 8 d. room tpt.—Fig. 6. *Act.* 6 VI. Aerial mycelium. Potato extract agar, 4 d. room tpt.—Fig. 7. *Act.* 6 S. Aerial mycelium. Dextrose agar, 2 d. 30° C.—Fig. 8. Same. Vegetative mycelium. Condensation water of nutrient agar, 2 d. 30° C.—Fig. 9. *Act.* 6 VI. Vegetative mycelium. Dextrose-NH_4Cl solution, 20 d. 30° C.—Fig. 10. Same. Vegetative mycelium. Potato, 3 d. 30° C.—Fig. 11. *Act.* A III. Vegetative mycelium. Dextrose broth, 4 d. 28° C.—Fig. 12. *Act.* 6 VI. Vegetative mycelium. Nutrient agar, 5 d. room tpt.—Fig. 13. *Act.* A III. Vegetative mycelium. Edge of colony on nutrient agar, 5 d. 28° C. Living specimen.

Plate xx.

Fig. 14. *Proact. paraffinae.* Vegetative mycelium. Dextrose agar, 10 d. room tpt. Acid-fast-staining.—Fig. 15. Same. Dextrose agar, 8 d. room tpt. Living specimen.—Fig. 16. *Proact. agrestis.* Dextrose agar, 1 d. 30° C.—Fig. 17. Same. Dextrose agar, 20 h. room tpt. Living.—Fig. 18. Same. Dextrose agar, 2 d. room tpt. Living.—Fig. 19. Same. Dextrose agar, 5 d. room tpt. Living specimen.—Fig. 20. *Proact. actinomorphus,* strain A II. Nutrient agar, 1 d. 30° C.—Fig. 21. Same. Saccharose-nitrate solution, 7 d. 30° C.—Fig. 22. *Proact. actinomorphus,* strain Rothamsted. Condensation water of saccharose agar, 4 d. room tpt.

All specimens are stained with dilute carbol fuchsin, unless otherwise stated. In Figs. 13, 17, 18 and 19 the magnification is × 350, in all other cases × 750.

THE WING-VENATION OF THE ORDER ISOPTERA. I.

INTRODUCTION AND THE FAMILY MASTOTERMITIDAE.

By R. J. TILLYARD, M.A., Sc.D. (Cantab.), D.Sc. (Sydney), F.R.S., etc.,
Chief of the Division of Economic Entomology, Council for Scientific and Industrial Research, Commonwealth of Australia.

(Plate xxi; eight Text-figures.)

[Read 30th September, 1931.]

Introduction.

The Division of Economic Entomology of the Council for Scientific and Industrial Research of the Australian Commonwealth is divided up into Sections which correspond with the principal economic problems whose solutions are being attempted. One of the most important of these is the problem of Termites or so-called "White Ants". Throughout the whole Continent of Australia, these insects cause immense damage annually to timber and structures built of timber. The prevention of this damage is a matter of the utmost importance to the Commonwealth. The total annual loss due to Termites, in the destruction of growing trees, railway sleepers, telegraph posts and cross-arms, fences and weatherboard houses, not to mention damage done to fruit trees, stored products of various kinds and even, in some parts, to grass-lands, is estimated at fully one million pounds sterling.

The Section of Forest Insects Research, under the charge of Mr. G. F. Hill as Senior Entomologist, has placed this problem in the forefront of its programme, and is acting in close co-operation with the Division of Forest Products and also with the Commonwealth Forestry Bureau in an endeavour to minimize the losses arising from Termites.

An important part of this work consists of a systematic survey of the species found in Australia and neighbouring countries. In the course of this survey, a very large amount of valuable material has been collected together, including what is probably the largest amount of living material ever assembled, for use in the field testing plots and laboratory colonies.

The total number of described species of Termites in the whole world is now about 1,600. Of these, already about 150 have been described from Australia, while some seventy more are known but not yet named and described. Many species and several genera have been inadequately defined, often being based on a type series that is incomplete in the sense that it does not include all the castes. Genera have been defined on characters which fuller experience proves to be unreliable. The position at the present time is such that it appears almost impossible to determine what some of the economic forms really are. Without accurate determinations of genera and species, the literature on the economic side must inevitably become more and more full of errors, and it is already abundantly clear that a thorough revision of the classification of the Order is needed.

To show how even the comparatively simple problem of the correct identity of two species may affect the economic problem, we need only mention the confusion which has arisen in the past between the two closely related species *Coptotermes lacteus* Frogg. and *C. flavus* Hill. It has been widely believed that *C. lacteus*, well-known as the cause of much damage to weatherboard buildings and also as the builder of large dome-shaped mounds in the bush, also attacks standing forest trees. Consequently, one method suggested for the protection of valuable forest reserves was the destruction of the mounds of this species. But it is now known that the species which attacks living trees is the closely allied *C. flavus*, which, on present evidence, does not form mounds at all! Hence the destruction of these mounds, though it would benefit anybody who wished to erect a weatherboard dwelling in the bush, would in no wise protect the standing timber.

A further difficulty arises owing to the unreliability of some of the characters at present used in classification. We have even noted an extreme case in which right and left wings from the same individual were classified into two distinct genera based on venational differences! It seems obvious that, even if no characters of value can be discovered in the worker castes, reliable genera in this Order should now be strongly based on a correlation of characters taken from the alate forms and the soldiers, and not merely from one or the other.

The accumulation of an immense mass of excellently preserved material offers an unrivalled opportunity for such a study, and the possession of large numbers of living forms allows more particularly of the carrying out of a piece of work which must surely yield particularly good results in the systematic field, viz., a study of the wing-tracheation of the developing nymphs. Mr. Hill and I have therefore agreed that we will undertake a joint piece of research, in which Mr. Hill's part will be to study the whole field of Australian Isoptera in order to find reliable characters for classification other than in the wing-venation, while I shall confine myself to a study of the developing wing-tracheation of the nymphs and the resulting wing-venation of the imagines. While following up these two lines of study we intend to write a series of papers correlating the results of our work.

I propose to divide my own share of the work into four parts, based on the four recognized families within the Order, viz., Mastotermitidae, Calotermitidae, Rhinotermitidae and Termitidae. The present Part deals with the family Mastotermitidae.

The Venation of the Family Mastotermitidae.

The moment that one begins to consider the venational problem presented by the Order Isoptera, there comes into view the archaic Australian genus *Mastotermes* Frogg., at the present time only represented by a single species, the Giant Termite of Northern Australia, *Mastotermes darwiniensis* Frogg. This species causes immense losses over a wide belt of Northern Australia. In many respects it may be said to hold the record amongst all insects for its powers of attack. Not only does it destroy all kinds of prepared timber except a few immune varieties but it does immense damage to living trees in the forest, to fruit trees and ornamental trees, and to various kinds of stored products. It has even been recorded as eating through lead-piping, and a remarkable instance is well authenticated in which it ate out the insides of some bonzoline billiard balls in a Darwin hotel! The winged forms swarm round the lights at periods ranging from late in November to early in February. Though winged forms and workers are very

abundant, nymphs are not so often met with, and many colonies appear to consist only of workers, soldiers and neoteinics. No true queen has yet been found, but it is believed that such does exist.

The most important piece of work requisite for a sound understanding of the wing-venation of Isoptera is undoubtedly a study of the nymphal tracheation in the genus *Mastotermes*. The opportunity to carry this out came to me in 1929 during a short visit to Townsville. Mr. Hill had informed me that all the fences and many of the trees in the hospital grounds of that city had been badly infested with *Mastotermes* when he was stationed there, and he asked me to send him supplies of living insects for his laboratory colonies in Canberra. When I reached Townsville in July, 1929, I found that the last of the wooden fencing had just been removed and was being replaced by concrete in order to save the heavy costs of almost continual renewals; so I turned my attention to the trees in the grounds. The hospital authorities very kindly gave me permission to cut down a large Poinciana tree which appeared to be badly infested. The tree was cut down and sawn into sections, and the roots were completely excavated. It was found that no connection existed between the *Mastotermes*-colony and the outside world, but that practically every part of the tree was tunnelled, and the roots were bored out right to their very ends. The resulting census of this colony showed that the tree contained about 100,000 workers in various stages of development, some 3,000 soldiers, and a few small and isolated colonies of a species of *Cryptotermes* in some of the branches. Nymphs of *Mastotermes* were especially sought for, but only two could be found, both in the penultimate instar and both living in galleries situated in rather small branches. It seems clear, therefore, either that nymphs are not produced every season in large numbers, or else that this colony, large as it was, was only an offshoot of some larger underground nest in which most of the nymphs were living.

The two nymphs were dissected in one of the laboratories at the School of Tropical Medicine in Townsville, where facilities for the work were kindly placed at my disposal by Dr. Richards. I wish here to thank him for his kindness and assistance. The results obtained will be described in detail in this Part.

As no nymphs of the last instar could be found, and as Comstock had already (1918) figured tracheae as still existing in the vein-channels of the wings of the imago, a search was later on made amongst Mr. Hill's material for last instar nymphs preserved in alcohol. One specimen from Groote Eylandt, Gulf of Carpentaria, appeared to me to be in excellent condition for dissection. In the dissected wing-sheaths of this specimen, tracheae were found almost as perfect as in the living nymph. The resulting drawings are made use of in this Part.

For a study of the imaginal venation, I have had the use of a number of slides of wings lent by Mr. Hill, and have also examined complete specimens of both sexes in alcohol. My best thanks are due to Mr. Hill for this valuable assistance.

A number of attempts have already been made by various authors to determine the homologies of the wing-veins in the genus *Mastotermes* without reference to the tracheation of the nymphal wings.* There are, however, some obvious anomalies in the venational scheme which make a satisfactory solution difficult, as the following comparative table of results will show:

* The paper by Claude Fuller entitled "The Wing Venation and Respiratory System of Certain South African Termites," *Ann. Natal Museum*, 1919, iv, pp. 19-102, does not, of course, include any reference to Mastotermitidae, but gives many figures of wing-tracheation in the other three families.

Table Showing Comparative Results for Wing-venation of the Genus **Mastotermes.**

	Desneux, 1904.	Silvestri, 1909.	Holmgren, 1911.	Comstock, 1918.	Tillyard, 1926.	Tillyard, 1931.
Forewing only	Sc	—	C	Sc_1	Sc	Sc
" "	—	—	C	Sc_1	Sc	Sc
Both Wings	Sc	C	Sc	Sc_2	Sc	Sc
" "	R	Sc	R_1	R_1	R_1	R_1
" "	R	Sc	R_1	R_2	R_{2+3}	R_{2+3}
" "	R	R	Rs	R_3	R_4	R_4
" "	R	R	Rs	R_4	R_5	R_5
" "	R	R	Rs	R_5	R_5	R_5
" "	M	M	M	M	M	M
" "	Cu	Cu	Cu	Cu	Cu_{1a}	Cu_1
Vena dividens (forewing only)	A	A	A	Anal Furrow	Cu_{1a}	Cu_2
Homologous Vein (in hindwing only) ..	A	A_1	A	1st A	Cu_{1a}	Cu_2
Vein anterior to anal fold (hindwing only)	—	A_2	Postanal	2nd A	Cu_{1b}	1A
Vein along anal fold (hindwing only) ..	—	—	—	Anal Furrow	Cu_2	$2A_1$
Veins posterior to anal fold	—	A	Postanal	3rd A	1A	$2A_2$
(hindwing only) ..	—	A	Postanal	3rd A	2A 3A	3A

Note.—The last column contains the results arrived at in the present paper. The most anterior vein of the wing is normally simple (except for small twigs) in the hindwing, but it is branched in the forewing; as there are usually two anterior branches of this vein separating off within the wing-stump of the forewing before the main branch, these are allowed for separately in the first two rows of the table.

Reviewing the above table, we note that there is absolute agreement amongst all the authors quoted in the case of one vein only, viz., the media. Opinions differ on all other important points, e.g., as to the presence or absence of a true costal vein apart from the subcosta, as to the limits of Sc, R_1 and Rs, as to the interpretation of the *vena dividens* of the forewing, and as to the limits of the anal venation and the composition of the veins of the anal lobe in the hindwing.

Apart from the present paper, Comstock is the only author who has made an attempt to utilize the wing-tracheation. Having no nymphs to work with, he nevertheless attempted to trace the tracheae in the veins of the imago. As a result, his conclusions come fairly close to those reached in the present paper through the study of the nymphal wing-tracheation.

I now propose to deal with (1) the wing-tracheation of the penultimate nymphal instar, (2) the wing-tracheation of the last nymphal instar, (3) the interpretation of the wing-venation of the imago in terms of the results so obtained, and (4) the problem of de-alation.

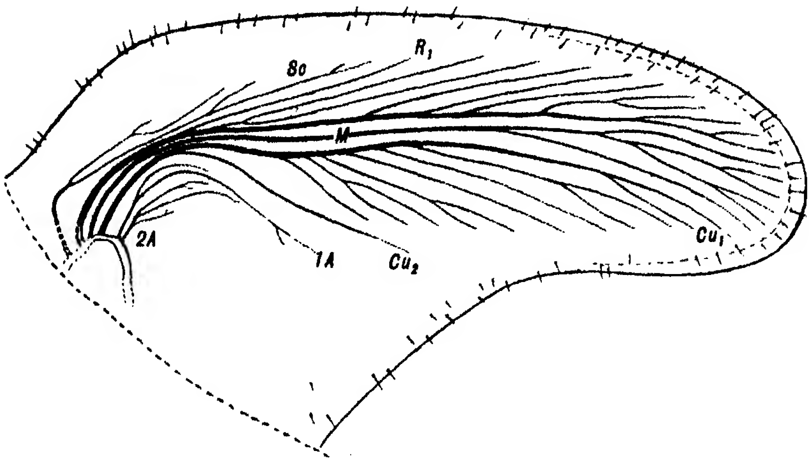
(1) *The Wing-Tracheation of the penultimate Nymphal Instar.* Text-figs. 1, 2.

The dissections of the wing-sheaths of the penultimate nymphal instar were made from freshly chloroformed material taken at Townsville, N.Q., by myself on 26th June, 1930. Only two nymphs were available. Text-figure 1 shows the tracheation of the forewing of one of these.

We note first of all the great breadth of the sheath, which, measured across the base where it was cut off, is almost exactly one-half of the total length.

Further, both anterior and posterior margins are very strongly arched, the former near the base, the latter about midway. This results in giving the impression that the wing-sheath began to grow in one direction and then turned more posteriorly. This impression is, I think, correct, as the position of the sheath with respect to the thorax strongly suggests that the basal part preserves to a considerable degree the original direction of a primitive paranotal expansion, and that, as this elongated, it tended to develop in a more posterior direction, as indicated by the distal portion. It would be very interesting to obtain the earlier instars of these nymphs in order to study the shape of the sheath in the successive instars from the first appearance of the wing-buds.

It is, unfortunately, almost impossible to dissect out the basal tracheal trunk complete, without badly disarranging the wing-tracheae, as it is rather deeply sunk in fat-tissue and not easy to see. I succeeded in preserving the posterior portion of it in the forewing, fortunately including therewith the actual origins



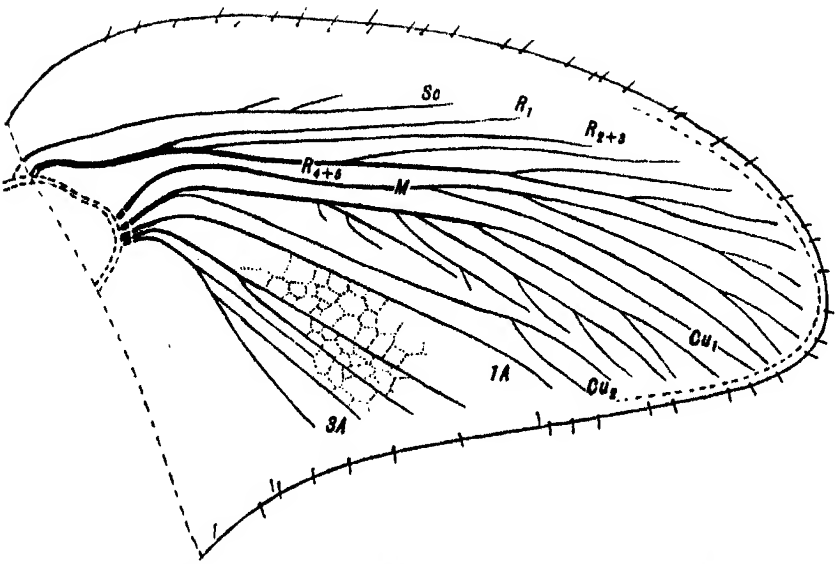
Text-fig. 1.—*Mastotermes darwiniensis* Frogg. Nymph, penultimate instar. Forewing, to show tracheation. Comstock-Needham Notation.

of the cubitus and anal veins; but the dissection cut across the origins of Sc, R and M. It was evident, however, that the tracheal trunk was stouter in diameter posteriorly than it is between the origins of Cu and the anal veins. This condition agrees closely with that found in a number of Cockroach nymphs, in which the original costo-radial and cubito-anal tracheal trunks are linked together into a complete loop by a middle connecting trunk of smaller diameter. In Text-fig. 1, I have restored the missing anterior portion of the trunk as on the supposition that it agreed with the Blattoid condition. Whatever may be the actual diameter of this trunk anteriorly, it is very clear that it formed a very deep loop, for this was the chief reason why I was unable to preserve it entirely in making the cut. As the cut left the main tracheae practically undisturbed in position, there is little difficulty in restoring the missing basal portions of Sc, R and M.

Text-figure 2 shows the tracheation of the hindwing of the same nymph as in Text-fig. 1. Here the breadth at base is enormous, even more than one-half the total length. The curvature of the wing-sheath, though marked, is not quite as

striking as in the forewing. My attempt to include part of the basal trunk trachea in the cut failed, although I made special efforts to reach the extreme base of Sc. However, the cut was made very near the actual origins of all the main tracheae, and I have given in Text-fig. 2 an approximate restoration of the position of the basal trunk.

Before proceeding to a description of the wing-tracheae, it is worth noting that the nymph dissected was evidently only in an early period of its instar, and was therefore in excellent condition for dissection. There was no rucking



Text-fig. 2.—*Mastotermes darwiniensis* Frogg. Nymph, penultimate instar. Hindwing, to show tracheation. Comstock-Needham Notation.

or crumpling of the tissues, and the courses of the tracheae were consequently very easy to follow. The outline of the developing wing-sheath for the last instar was only just beginning to show itself distally within the existing sheath, hence my attempt to discover any indication of the limits of either the wing-stump of the forewing or the anal lobe of the hindwing did not meet with any success. An interesting occurrence in the hindwing was, however, noted in the beginnings of a sort of polygonal meshwork posterior to 1A. It will be seen, later on, that this area becomes secondarily invaded with branch tracheae from 1A, which is originally developed as an unbranched trachea.

A comparison of Text-figs. 1 and 2 shows that, in both wings, only four main tracheae exist in addition to the anal group. In the forewing (Text-fig. 1), only two short, rather weakly formed anal tracheae exist; in the hind (Text-fig. 2) there are three, much more strongly developed.

This analysis of the system of main tracheae shows us at once that there is no distinct costal trachea present in either wing. Comstock himself recognized this, so that we can safely reject the interpretations of Silvestri and Holmgren, who consider that a separate costal vein was present in the imaginal wing.

The Subcostal Trachea.—Apart from small anterior twigs, this trachea is usually unbranched in the hindwing (Text-fig. 2), hence there can be no difficulty in recognizing it. In the forewing, however (Text-fig. 1), its course is very arched basally, not far from its origin, and thus separated thereabouts quite considerably from the radial trachea posterior to it. Just distad from the arched portion, it gives off a basal anterior branch which is itself bifurcate. If this branch were constant, we should be justified in following Comstock's usual notation and designating it Sc_1. Unfortunately, however, it is not so. The examination of a series of imaginal forewings, as well as the study of the tracheation in the only available specimen of the last nymphal instar, indicates that the branching of Sc is highly variable, so that I consider it wiser to keep merely to the notation Sc for the complete trachea.

It may be noted, however, that this basal branch evidently occurs in a large number of forewings, and that it sometimes bifurcates even within the area destined to form the imaginal wing-stump; this was evidently the case in the nymphal wing here being studied, and also in the forewing figured by Holmgren (1911); he labels the corresponding portion of the venation "C".

The subcostal trachea ends distally less than half-way along the wing in the forewing, at about half-way in the hind.

The Radial Trachea.—As is to be expected, the radial trachea is the stoutest trachea in the whole wing. Moderately arched near the base in the forewing (Text-fig. 1), it runs for a space very close to both Sc and M, and then straightens out and runs the whole length of the wing to a point just above the apex. For the whole of its length, not a single posterior branch is given off; the whole system of branches of this trachea is anterior to the main trunk.

The first anterior branch is given off just as the trachea is straightening out after its basal arching. This branch is slender and runs just below and subparallel to the main stem of Sc, ending up only a little beyond it. Just distad from this branch, in the specimen under description, there arises another slender branch which bifurcates almost immediately, its two slightly diverging branches running to the costal border a little beyond half-way. Beyond this there are three more simple branches, subparallel to one another, then a shorter branch which bifurcates, followed by one more simple branch and a short terminal fork.

In the hindwing, the radial trachea arises closer to the subcostal, and has a general formation fairly closely similar to that of the forewing. The branches are, as in the forewing, all anterior, but they are only five in number and are all simple. It is interesting to note that, in both wings, the first two branches arise close together from the main stem.

The formation of the radial trachea, with its anterior system of branches, is a markedly Blattoid character. The normal type of radial trachea and vein, in other insects, is an anterior convex main stem, R_1, with a posterior concave sector, Rs, considered by Comstock to have been originally dichotomically divided into four branches, R_2 to R_5. While it is very doubtful whether Rs was originally either four-branched or dichotomically branched in the first winged insects, there can be little doubt that the division of R into an anterior convex R_1 and a posterior concave Rs is a primitive character, for it can be seen in nearly all known Carboniferous insects, including the Protoblattoidea, and is also well marked in some of the Carboniferous Blattoidea. The evolution of this latter group has, however, been along the lines of gradual recession of the area occupied by the subcosta and

invasion of that area by the radius. Thus the original R_1, instead of being a long trachea or vein running very nearly to the apex (as in Mayflies, for instance), has followed the subcosta basad, and become shortened in the process to a mere anterior branch of Rs. It has been followed in the same manner by R_2, R_3, R_4 and even by the more anterior branches of R_5; in the venation, each one of these, as it invaded the territory originally occupied by Sc, has tended to become more or less convex in conformity with the general convex tegminization of the wing.

If, therefore, we agree that the normal terminology of the Comstock-Needham system is applicable at all to the Blattoid type of radius, it is clear that only the most basal anterior branch can be considered as R_1, while all the rest of the radius must be considered as radial sector. In so far as it is worth while to distinguish the parts further, the second anterior branch must be named R_{2+3}, and we may see in its bifurcate condition in the forewing (Text-fig. 1) evidence of its primitive dichotomy into R_2 and R_3, which has apparently disappeared in the hindwing (Text-fig. 2). All the rest of the strong main stem is properly R_{4+5}, but only the most anterior branch of this can be assigned to R_4, while the remainder must be considered as R_5. It follows that it will be most convenient to consider the main radial trachea and vein in Isoptera as simply the radial sector, distinguishing its most basal anterior branch only as R_1 if occasion arises.

The Median Trachea.—In the forewing this trachea arises just below the radius, but in the hind it arises far away from that vein and is associated purely with the cubito-anal group. In both wings it is basally arched and then runs for some distance without branching. The branches develop only from about half-way onwards, and are of the usual posterior type, but apparently with considerable variation in detail in individual wings, as may be seen by comparing Text-figs. 1–4. This variation renders any attempt to distinguish the four main branches postulated by Comstock and Needham more or less valueless, and it seems sufficient to recognize the median trachea as a whole, and simply to label it "M".

The Cubital Trachea.—This is the most characteristic trachea in the wing. In both fore- and hindwings, it is divided into a strongly developed anterior branch, Cu_1, with a number of descending branches forming a pectinate series, and a much slenderer and simpler posterior branch, Cu_2, originating not far from the base and before the basal arching is complete. This branch is either simple, as in the forewing in Text-fig. 1, or it may be terminally twigged as in the hindwing in Text-fig. 2. A reference to the imaginal venation (Text-figs. 5, 6) will show at once that it is this trachea which follows the course of the *vena dividens* in the forewing and thus serves to divide the anal area from the main part of the wing: but equally, by reference to the hindwing venation, it will be seen that it lies far anterior to the anal lobe in that wing, and takes no part in delineating the anal fold there.

Comstock quite correctly interpreted the corresponding trachea in his figures of Blattoid nymphal wings (1918, pp. 124, 125, figs. 116, 117), but failed to homologize it correctly with the corresponding vein in the imaginal wing (l.c., figs. 118, 119). Some of his followers have insisted on perpetuating this error and applying it generally to all types of wings, with the result that they destroy the whole basis of the Comstock-Needham system. For it is the basic essence of that system that the veins of the imaginal wing should take their names from the tracheal trunks from which they are derived. Now the vein which I here call Cu_2 has its trachea always arising from trachea Cu; hence, if it is to be called 1A, the whole basis of the system falls to pieces. I have no objection whatever to

its being called CuP (posterior cubitus), as Lameere and Martynov propose, in which case the anterior cubitus should be termed CuA instead of Cu_1; but to term it 1A is absurd, when it is in no sense of the term an anal vein and is not derived from an anal trachea.

The question of objection to the use of terms such as Cu_{1a} and Cu_{1b} does not arise in considering the Isoptera, since Cu_1 is not dichotomically branched and there is little point in naming the individual branches of a variable pectinate series.

The Anal Tracheae.—In the forewing (Text-fig. 1) we distinguish clearly two anal tracheae, viz., 1A and 2A. Trachea 1A is delicately formed by comparison with the more anterior tracheae. It follows a very arched course, roughly concentric with the arched portion of Cu followed by Cu_2 above it, but diverging slightly from it distad. A short anterior branch runs in the curve of the arch between its main part and Cu. Trachea 2A is much shorter, arising just below 1A, equally delicately formed, and fills part of the space below the arch of 1A, branching irregularly into three.

Very different is the formation in the hindwing (Text-fig. 2). Here there appear to be three distinct anal tracheae, 1A, 2A and 3A, all arising close together and much better developed than in the forewing. 1A is an unbranched trachea running fairly close below and sub-parallel to Cu_2. Between it and the narrowly branched 2A there is a rather wide space, already noticed as carrying an initial development of irregular polygonal cells. A similar but less marked development of cells is indicated below 1A, between the two branches of 2A, and also distally just below 2A. Trachea 3A runs just below 2A, but branches somewhat earlier into three, the anterior branch being the shortest.

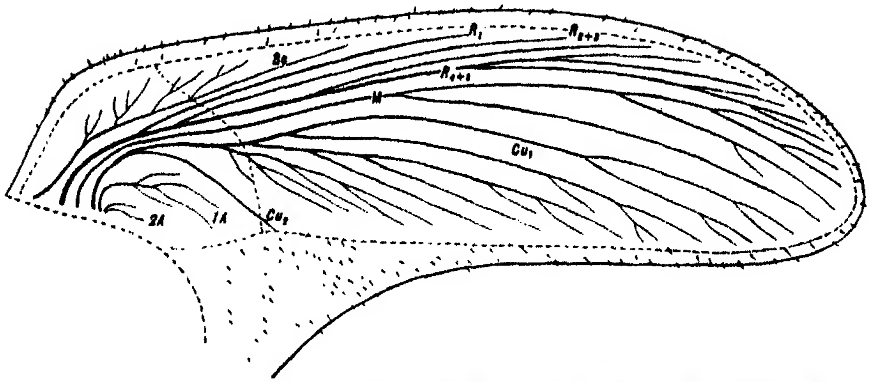
(2) *The Wing-Tracheation of the Last Nymphal Instar.* Text-figs. 3, 4.

No living material of this instar has been available for dissection, but one nymph preserved in alcohol in Mr. G. F. Hill's collection was found to be in very good condition, having evidently been captured very soon after it had attained its final instar. A dissection of this showed the tracheae still *in situ*, so that I was able to make the drawings given in Text-figs. 3, 4, for comparison with those of the previous instar.

The chief difference to be noted in the shape of the wing-sheaths is their much greater elongation. The basal arching or bending is preserved, especially in the forewing. Fortunately the whole outline of the actual wings of the imago, in process of formation within the sheath, could be made out, and is shown by a fine dotted line in the figures. By following along the posterior margin, the distinct though slight inbending can be noted which marks the end of the *vena dividens* in the forewing and the anal fold in the hind. We then see quite clearly that these two formations are not homologous in fore- and hindwings; for the *vena dividens*, bounding the true anal area of the forewing, is obviously Cu_2 by comparison with Text-fig. 1, whereas the anal furrow in the hindwing runs along the course of the anterior branch of 2A!

There is no need to follow the courses of the tracheae in detail in this instar, but only to note the points in which they differ from those of the previous instar. In this particular forewing, the branchings of Sc are very irregular, consisting of four anterior veinlets, each of which is twigged. R_{2+3} is unbranched, as in the hindwing in Text-fig. 2, but still arises close to R_1. The total number of anterior branches of R is rather markedly diminished; three branches, R_1, R_{2+3} and

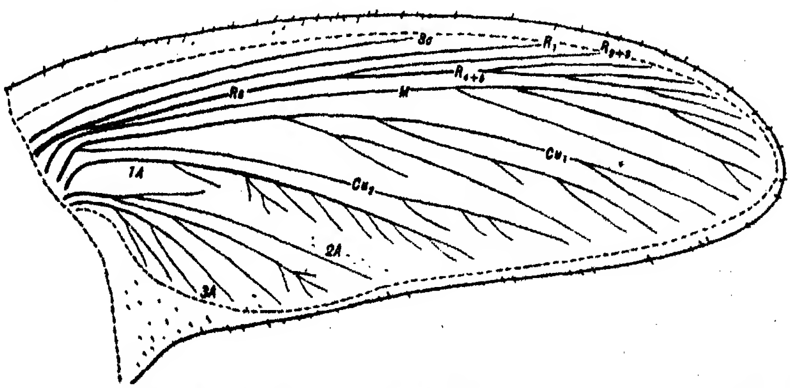
R_{4+5}, cross the suture of the wing-stump (Text-fig. 3). The first posterior branch of M arises a little before half-way. The general course of Cu is little altered, but Cu_1 is more arched near the middle of the wing, and most of the branches of its pectinate descending series tend to collect close together near the point where



Text-fig. 3.—*Mastotermes darwiniensis* Frogg. Nymph, last instar. Forewing, to show tracheation. Comstock-Needham Notation. The transverse dotted line indicates the position of the wing-suture.

this arching begins; they are also reduced in number, but are individually more branched than before. There is evidently very great irregularity in the form of these branches in individual wings.

Very notable is the reduction in size in Cu_2 and the anal tracheae. In the previous instar (Text-fig. 1) Cu_2 reached very nearly half-way along the wing; it now ends at little more than one-fourth. Also its course is now a still more definite arch than before. Within this arch can be seen the shortened and now quite irregularly branched trachea 1A together with a mere remnant of 2A in the form of two very short tracheae. At this early stage in the instar the outline of the



Text-fig. 4.—*Mastotermes darwiniensis* Frogg. Nymph, last instar. Hindwing, to show tracheation. Comstock-Needham Notation. The re-entrant angle of the posterior margin, indicating the limits of the anal lobe, is shown on the dotted line at the end of the trachea labelled 2A.

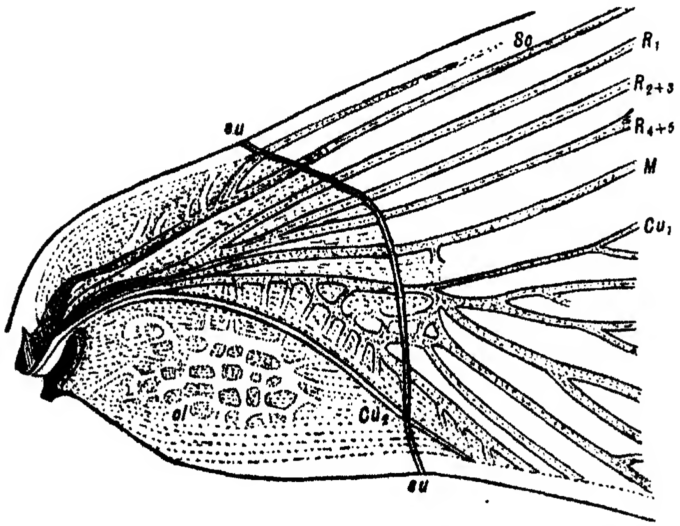
suture destined to separate the wing-stump from the rest of the wing cannot be clearly seen, but its future position can easily be inferred by reference to the imaginal venation, and is indicated in Text-fig. 3 by a dotted line traversing the basal quarter of the wing.

In the hindwing (Text-fig. 4) the changes are not great. Sc is now entirely without veinlets. Rs diverges slightly downwards after departing from R_1, thus tending to come very close to M. There is no important change in M and little in Cu_1 beyond a reduction in the number of descending branches. Cu_2 remains very long, reaching to a point about two-thirds along the posterior margin. 1A also remains long, and now sends a series of descending twiglets into the wide space in which we had noted, in the previous instar, a partial formation of a polygonal meshwork. Each of the two main branches of 2A has developed secondary branches; the main anterior branch of 2A runs along the course of the future anal fold, with the two well-formed branches of the posterior portion lying in the anal area below it. 3A is now four-branched, and supplies the lobed portion of the same area. The inbending of the posterior margin which indicates the termination of the anal fold lies at a point about two-fifths of the wing-length along that margin.

(3) *The Venation of the Imaginal Wings.* Text-figs. 5, 6.

The study of the wing-tracheation of the last two nymphal instars has now prepared us completely for a full interpretation of the imaginal wing-venation. This is shown in Text-figs. 5, 6. The following points may be specially noted:

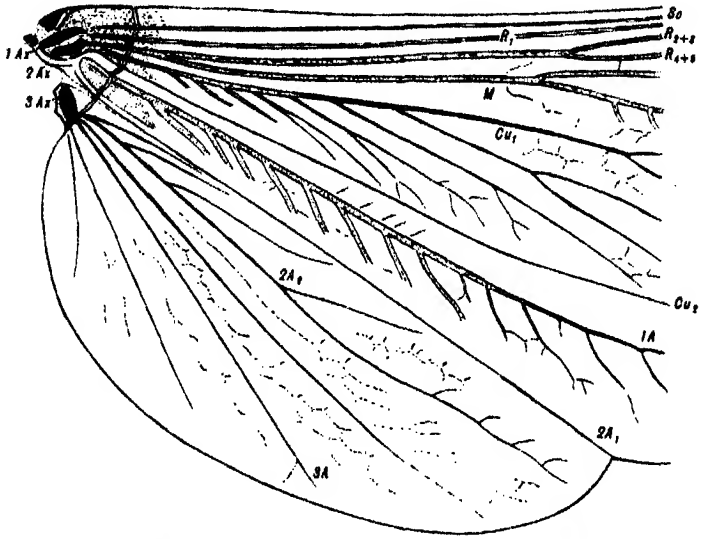
(1). In neither wing is there any evidence of the development of a true costal vein distinct from the subcosta. In the forewing, the short branches some-



Text-fig. 5.—*Mastotermes darwiniensis* Frogg. Imago. Base of forewing, to show the wing-stump, the suture (*su*) along which the wing separates off at de-alation, the *vena dividens* (Cu_2) and the Blattoid form of the anal area or clavus (*cl*).

times found anteriorly within the wing-stump are properly to be considered as anterior branches of Sc, not as vein C.

(2). The main anterior longitudinal vein of the wing, with a number of anterior branches, is correctly termed the radial sector. Its most basal anterior branch is the original R_1; there would appear to be little value, within the Order Isoptera, in naming the separate branches of Rs, as they are obviously very variable.



Text-fig. 6.—*Mastotermes darwiniensis* Frogg. Imago. Basal portion of hindwing, including the whole of the anal lobe. The line along which the wing breaks away at de-alation is shown by the double transverse lines close to the base (see also Text-fig. 7). The three axillaries are labelled *1Ax, 2Ax, 3Ax* respectively, the last-named being separated from the other two by a thin membranous area. $2A_1$, anterior convex branch of 2A which forms the anal fold. $2A_2$, posterior branch of 2A with secondary anterior branches.

(3). No doubt exists as to the identity of vein M in the forewing. The approximation of Rs near its origin from R_1 towards M in the hindwing of the last larval instar prepares us for its basal fusion with M in the imaginal hindwing. This character is universal in the Orders Isoptera and Perlaria.

(4). No doubt exists as to the identity of vein Cu_1 in either wing. The more basal descending branches of this vein tend to flatten out in the forewing, and within the wing-stump they are partially atrophied. In the hindwing, they also tend to stop short in the membrane as they approach Cu_2.

(5). The *vena dividens* in the forewing is a weakly chitinised concave vein and forms the anal furrow. It is undoubtedly Cu_2. In the hindwing, the homologous vein is also very lightly chitinized, but lies far anterior to the anal fold.

(6). The anal area or clavus of the forewing is of the strongly arched Blattoid type. The anal venation has degraded, and is replaced by an irregular polygonal meshwork, usually very faintly indicated.

(7). The anal lobe of the hindwing is not coterminous with its anal area, but is remarkable in being bounded anteriorly by the most anterior branch of 2A, which in the imago is barely chitinized and forms the anal fold. Vein 1A, lying anterior to the lobe, tends to duplicate Cu_1 in form, but somewhat on a reduced scale, through the formation of hypertrophied descending branches which stop short before reaching 2A. The branchings of the posterior main branch of 2A and also of vein 3A within the anal lobe are highly irregular, and an indefinite polygonal meshwork is developed between them. At the base of the wing, the third axillary (Text-fig. 6, *3Ax*) is seen to be well separated from the first and second axillaries (*1Ax, 2Ax*) by an area of thin membrane; the veins 2A and 3A spring directly from the third axillary.

It should be noted that the anal fold of the hindwing is a convex fold, the anal lobe folding along it beneath the rest of the wing. The *vena dividens* of the forewing, on the contrary, is a concave furrow (anal furrow of Comstock). It is therefore unfortunate that Comstock applies the same terminology, "anal furrow", to both these structures.

As regards the exact composition of the vein M, according to Lameere's terminology, I have so far said nothing. The position would appear to be similar to that in the Blattoidea, where, so far as I am aware, there is no evidence of a division into distinct anterior median (convex) and posterior median (concave) at all. Tegminization of the forewing in the Blattoidea has made all the veins except Cu_2 appear more or less convex; but a reference to the hindwing, as well as to both wings in the Mantoidea, makes it fairly certain that the media is really only the posterior median, MP, of Lameere. Whether an original anterior median, MA, has taken any part in the formation of the vein which we now call the radial sector is a question which must for the present be left open. To determine this, we need clear evidence as to what group of Blattoidea or Protoblattoidea are the actual ancestors of the Order Isoptera. Such evidence, at present, appears to be entirely lacking.

That the Isoptera are closely related to the Blattoidea is now quite certain, and this conclusion is still further strengthened by the present study. We have now to decide whether the family Mastotermitidae lies along the direct ancestral line or not. The main difficulty lies in the interpretation of the anal lobe.

In all Blattoidea and Mantoidea the folded portion includes the whole of the anal venation, whereas, in *Mastotermes*, 1A lies wholly outside the folded portion, and the folding itself takes place along the anterior branch of 2A. This fact may be interpreted in one of two ways: either *Mastotermes* is descended from ancestors which, like all other Isoptera, entirely lacked the folded anal area, and, later on, a secondarily enlarged folded area has been developed with a different boundary, or else *Mastotermes* exhibits a reduction-stage in the transition from the normal Blattoid or Mantoid type of hindwing to the normal lobeless type of the rest of the Isoptera, the reduction having been effected by the transference of vein 1A from the original folded area on to the unfolded portion of the hindwing.

All the evidence appears to me to favour the second supposition. In the original Blattoid and Mantoid type of hindwing, Cu_2 is a long and weakly chitinized concave vein, forming the *vena dividens* which separates off the anal area from the rest of the wing. Running closely below it is the convex vein 1A, along which the actual underfolding of the anal lobe takes place. Usually there is a break in

the form of a re-entrant angle in the posterior margin at the end of Cu_2; but there are many Mantoid types in which the contour of the posterior margin is continuous, and some Blattoids in which the break is only very slight. The development of the condition found in *Mastotermes* from the normal Blattoid condition requires (*a*) the elimination of the re-entrant angle at end of Cu_2, so that the posterior margin should form a continuous curve, (*b*) the possession, in the ancestral form, of a branched 2A, and (*c*) reduction of the folded area by transference of vein 1A on to the unfolded portion, the secondary folding taking place instead along the line of the anterior branch of 2A. We have already seen that condition (*a*) offers no obstacle to the theory that *Mastotermes* lies in the direct ancestral line. As regards condition (*b*), it is sufficient to note that 2A is normally branched both in Blattoids and in Mantoids, and there are many types in which the development of a long anterior branch, itself simple and suitable to function as a secondary anal fold, is obviously quite possible. Condition (*c*) would then be fulfilled, most probably, if, during the course of evolution, there were to take place a disproportionate change in the length of the veins, as, for instance, in the event of an inordinate lengthening of the wings. Such a lengthening would carry the original *vena dividens* far out beyond the end of the abdomen of the insect, as has actually happened in the case of *Mastotermes*, with the result that the folded area would no longer be entirely protected beneath the body. If the manner of folding were to remain the same, i.e., about a convex fold, it is clear that the next position suitable for folding must develop along the first branch of 2A, as has happened in *Mastotermes*.

Now the length of the forewing in *Mastotermes* is about 30 mm., that of the hindwing about 28 mm. The abdomen, however, is only 10 mm. or somewhat less, and the distance from the base of the hindwing on the metanotum to the end of the abdomen is about 12 mm., which is the same as the length of the anal fold. Thus the folded portion, when in the position of rest, fits neatly over the abdomen, and does not project beyond it so as to risk tearing. I think it will be admitted that the length of the wings in *Mastotermes*, and, indeed, in all Isoptera, is out of all proportion to the length of the abdomen, and that very definite elongation of the wings must have taken place at some stage in the evolution of the Order. Therefore it appears that a clear case has been made out for the view that *Mastotermes* lies in the direct ancestral line of the evolution of the Order, and retains an intermediate condition in the reduction of the folded anal area by transference of the actual fold from the convex vein 1A to the convex anterior branch of 2A.

(4) *The Problem of De-alation.*

De-alation is the process of shedding the wings. In the high development of this process, the Order Isoptera is the most specialized of all Orders of Insects.

In the Isoptera, alate individuals of both sexes normally shed their wings at some period after their emergence. But there is a great deal of difference between the lengths of time usually taken before de-alation occurs in different groups, and also in the ease with which the wings are shed. Normally, however, both pairs of wings are shed with equal ease.

The small basal portion of the wing which is left attached to the thorax, after de-alation has taken place, has been called the wing-stump, wing-stub or wing-scale by various authors. The last of these expressions is the one most commonly in

use; but it is open to the serious objection that it is already in use for an entirely different structure, viz., the wing-scales of butterflies, moths, mosquitoes and other insects. I therefore propose to use the term wing-stump in this and subsequent papers, since that term exactly describes the piece of the wing which is left behind, and is not in use for any other structure.

Normally, the fully developed wings of Isoptera have a transverse line of weakness, the basal suture (Text-fig. 5, *su*), clearly marked between the wing-stump and the remainder of the wing. The insect gets rid of its wings merely by pushing or rubbing against any convenient rough surface, or by some action which causes bending of the wings at the sutures, such as raising the abdomen, or raising the thorax high on the legs so that the tips of the wings press against the ground or object on which the insect is standing. In the majority of cases, even very moderate pressure or displacement is sufficient to rupture the wing along the suture, and de-alation results at once. But, as will be seen later when we come to study other groups of Isoptera, there are some cases in which the wings are not so easily shed.

As de-alation is a highly specialized phenomenon, and is better developed in the Isoptera than anywhere else, it appears reasonable to suppose that characters of considerable value in a scheme of classification for the Order ought to be found in connection with it. I propose, therefore, to consider the nature of the wing-stump and basal suture in the various families of Isoptera, together with the differences which may exist in them in the fore- and hindwings.

The Mastotermitidae differ from most other Isoptera in the fact that, while the forewing possesses a well-developed basal suture and large wing-stump (the latter measuring in length about one-ninth of the total length of the wing), the hindwing does not appear to show any sign of a true suture at all. Further, living specimens have frequently been found in which the forewings have been shed whilst the hindwings have been retained. It is true that, in the end, both pairs of wings are shed; but it is also true that the hindwings are often retained much longer than the fore.

If a winged specimen of *Mastotermes* be taken out of alcohol and held in the fingers or by the forceps, it can easily be verified that a slight pushing or bending of the forewing will cause the wing to split along its basal suture, which is always very clearly marked. The crack appears first inwards from the costa across Sc and R, and then opens up rapidly as far as Cu_2. *From this vein to the* posterior margin is only a small distance; yet this part does not yield as readily as the rest, and the final tear may either take place obliquely along the course of Cu_2, or it may continue the transverse course already begun, leaving the tip of Cu_2 itself on the de-alated portion of the wing. An examination of specimens de-alated naturally while alive shows that the latter method is by far the most usual. Occasionally, however, one sees the oblique tear along the course of Cu_2. Occasionally, also, it happens that the suture runs to the posterior margin either exactly at the end of Cu_2, or even slightly distad from it. In the latter case, the whole of vein Cu_2 is left on the wing-stump, as is the case with the forewings of other families of Isoptera known to me. In the majority of specimens examined, the distal part of Cu_2 lies just beyond the wing-stump, as in Text-fig. 5.

Now if we try to remove the hindwing of a specimen of *Mastotermes* taken from alcohol, we shall find that it is by no means as simple a task as in the case

of the forewing. One can press the wing forward towards its base with quite considerable force, and still obtain no result. However, if sufficient buckling of the wing can be obtained, a split will occur close to the base, from costa to Sc only, and nearly at right angles to the former. If, now, further bending or pushing is continued, this split can be made to open up transversely across the other veins, as far as the end of the chitinized block which lies at the base of 1A. Owing to the separation of the third axillary (Text-fig. 6, *3Ax*) from the other basal chitinized structures of the hindwing, the attachments of this wing to the thorax consist of two blocks of fairly hard chitin separated by a thin membrane in the region of the anal fold. In following out the progress of the split, it will thus be seen that it has now reached a point impinging upon the anal fold itself. Along this same fold the hindwing, in the position of rest, is folded in such a way that the anal lobe lies beneath the rest of the wing. If the pushing or bending of the wing is continued still further, the next result will either be that a tear will take place along the anal fold, or irregularly across the anal lobe, or it may happen that the original split will be continued across the anal fold and follow an irregular course across the other anal veins. If the transverse splitting is continued in this last manner, as shown in Text-fig. 6, then the branches of 2A and 3A will be found to be severed practically at their origins with the third axillary, where they are weakly chitinized. This appears to be what usually happens in nature. But it would be worth while to examine a large number of naturally de-alated individuals, in order to determine what percentage of them do actually succeed in ridding themselves completely of the anal lobe of the hindwings.

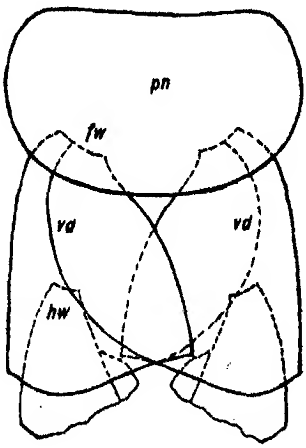
Two important characters emerge from this study of the process of de-alation. The first is that the forewing possesses a definite basal suture, while the hindwing does not. The second is that the wing-stump of the forewing is much larger than that of the hind. The first character is one in which the Mastotermitidae differ from all other Isoptera studied by me. It is obvious that the sutureless condition of the hindwing is an archaic character, and that it is at any rate partly correlated with the preservation of an anal lobe. The second character does not serve to distinguish the Mastotermitidae from the more archaic groups in the rest of the Order, e.g., the Calotermitidae, in which also we may note a marked difference in the size of the wing-stumps of fore- and hindwings.

It does not seem likely that we can definitely prove the method whereby the living individuals of *Mastotermes* rid themselves of their hindwings, except by actual observations on living specimens before de-alation. But a study of the two wing-stumps *in situ* is very suggestive. If we take a specimen from alcohol and remove its forewings, which can be done with ease, and also without injury to the hindwings, then we note, first of all, that the wing-stump of the forewing is slightly convex, and that it presses down firmly upon the base of the hindwing. The suture between metathorax and abdomen lies slightly distad from the free edge of the fore wing-stump. There appear, then, to be two fulcral lines along which the hindwing might be bent and split in nature; the first would be along the hard edge of the fore wing-stump, while the second would be slightly distad from this, just over the suture between thorax and abdomen. Experimentally, I have succeeded in inducing splitting along both these lines, but it is much easier to do it along the hard edge of the fore wing-stump than along the other position. If the hindwing be simply seized with the forceps and bent upwards against the fore wing-stump, it will split along the line of bending, at any rate as far

as the anal fold. But to achieve the second result, it is necessary for the abdomen to be raised upwards until the hindwing is actually caught between the concavity of the suture between thorax and abdomen below it, and the sharp edge of the fore wing-stump above it; when that happens, a similar split takes place, but slightly distad from the line of the fore wing-stump. This operation cannot be done easily with a specimen taken from alcohol, owing to loss of elasticity in the abdomen. But it is conceivably quite an easy operation for the living insect.

Examinations of specimens taken alive in the de-alated condition, from Mr. Hill's collection, indicate that, in all cases, the split in the hindwing is placed slightly distad from that of the fore. This can be well seen in Text-fig. 7. This fact may be interpreted either as proving that the second method of de-alation, mentioned above, is the actual process employed in nature, or it might still be argued that it is the first method that is employed, and that subsequent swelling of the tissues during immersion in alcohol has caused the displacement now noticeable. Mr. Hill, however, informs me that, in preserving his specimens, he changed the alcohol frequently, after death of the specimens, for the express purpose of avoiding distension of the body tissues. My impression, after studying a considerable number of his specimens, is that no appreciable change in the position of the thoracic structures has taken place. Therefore I strongly incline to the second explanation, as stated above. But, as I said before, the actual proof of this point must await observations in the field.

Let us now return to our study of the naturally de-alated specimen, as shown in Text-fig. 7. Under the microscope, the difference in the natures of the distal



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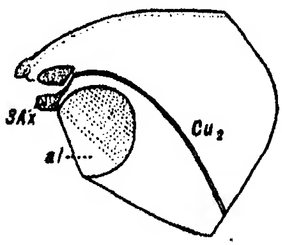

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Text-fig. 7.—*Mastotermes darwiniensis* Frogg. Diagram of part of imago, to show the pronotum (*pn*) with the wing-stumps in position after de-alation. *fw*, *hw*, bases of attachment of forewing to mesonotum and of hindwing to metanotum; *vd*, *vena dividens*. Note the close alignment of the severed ends of the two pairs of wings, and also the alignment of the *vena dividens* with the severed ends. The parts which are covered by other structures are shown by dotted lines; the left forewing overlies the right, and both forewings overlie the hindwings. The posterior part of the lobe of the pronotum overlies the bases of the forewings.

Text-fig. 8.—Diagram of forewing-stump, viewed from beneath, to show position of alula (*al*). *3Ax*, third axillary; Cu_2, *vena dividens*.

margins of the two wing-stumps can be easily made out. In the forewing, there is no sign of tearing; the main veins are all clearly weakened at the points where they impinge upon the suture, and the intervening membrane is also neatly separated along the sutural line, not torn off roughly. But in the hindwing, the main veins are evidently broken off, while the intervening membrane is torn off irregularly between them. Thus the distal margin of the fore wing-stump is fairly regular, while that of the hind is more or less jagged.

Measurements of the two wing-stumps show that, whereas that of the forewing is about one-ninth of the total length of the wing, that of the hindwing is not quite one-sixteenth of the total length. In actual area, the wing-stump of the forewing is much greater than that of the hind, since it is wider as well as much longer. A careful calculation gives the ratio of the areas as about 8:3. Striking as these differences are, they are nevertheless exceeded in some genera belonging to the Calotermitidae.

For purposes of comparison with other groups, we have also to bear in mind the markedly Blattoid form of the clavus or anal area of the forewing in *Mastotermes*. This is undoubtedly a very primitive character; so far as I know, it is unique within the Order Isoptera. The Blattoid form of clavus is due chiefly to the marked curvature of vein Cu_2 concavely to the posterior margin. Even in those Calotermitidae in which the form of the fore wing-stump most closely approaches that of *Mastotermes*, it will be seen that this concave curvature of vein Cu_2 has been lost.

Another character which appears to promise well for comparison with other groups is the actual course of the split in both wings. In the forewing of *Mastotermes*, it runs obliquely downwards and outwards from the costa as far as R_{4+5}, then turning to run transversely as far as Cu_2, whence it turns slightly outwards to reach the posterior margin. Such a course may be described as convex to the base, with its principal bend or angle on or near R_{4+5}. The course of the split in the hindwing (which, we have already shown, is not a true suture in *Mastotermes*) is also convex to the base, with a slight bend or angle at Sc, and thereafter somewhat irregular. Deviations from this primitive type will be carefully noted in our studies of the higher families.

The Alula of the Forewing (Text-fig. 8).—During the examination which I made of the process of de-alation, I lifted up with the flat blade of a scalpel a complete forewing of a specimen of *Mastotermes* taken from alcohol. In this case, the wing did not break as easily as usual at the suture, and I succeeded in raising it to an angle of about sixty degrees from the body. I was then extremely surprised to see standing out at a slight angle beneath the extreme base of the wing a small lobe, which at once reminded me of the alula of the Coleopterous family Hydrophilidae. Carefully slipping the scalpel along beneath this, I sliced the wing off below it. The wing was then turned over and examined in alcohol and a drawing of the alula made (Text-fig. 8). It consists of a more or less rounded flap, joined to the basal part of the clavus by a wide chord or base of attachment, the anterior end of which is very close to the third axillary. The free rounded part of the alula is more or less deeply pigmented in brown, but a rather triangular area in contact with the base of attachment is so completely hyaline as almost to escape detection at first sight. The alula folds closely under the clavus, its outer margin not reaching as far as the *vena dividens*. It thus bears much the same relationship to the clavus of the forewing as the anal lobe of the hind bears to the rest of the anal area of that wing.

It seems strange that this structure should have previously escaped detection, but such appears to be the case. In order to make sure that I was not mistaken, I asked Mr. Tonnoir to dissect another forewing from a specimen of *Mastotermes* in the same manner, and he discovered in this specimen a similarly placed lobe, an undoubted alula, which only differed from the one found by me in being slightly smaller and more oval in form, and had the same hyaline appearance at the base.

We may therefore take it as proved that there is a true alula of the type found in certain Coleoptera in the forewings of *Mastotermes*. The structure should be searched for also in other primitive genera of Isoptera, and will very probably be discovered, perhaps in an obsolescent form, in some of them.

Whether this curious structure has any phylogenetic significance or not, I am not prepared to say at the present moment. The Hydrophilidae are admittedly a very archaic family of Coleoptera, but it does not yet appear to be established that the alula was present in the ancestral type of elytron for that Order. If that were so, then the presence of a similar organ in *Mastotermes* might be held to indicate a community of origin for the Orders Isoptera and Coleoptera. This problem, however, lies beyond the scope of the present paper.

Summary of the Characters of the Wings in the Family Mastotermitidae.

We are now in a position to define the family Mastotermitidae on the characters of its wings, as follows:

Forewing.—Wing-stump large, its length measured from the base along vein M being about one-ninth of the total length of the wing. Wing-suture convex to base, with a bend or obtuse angle about vein R_{4-5}. Anal area or clavus of Blattoid form, with the *vena dividens* (Cu_2) curved concavely to the posterior margin; normally, this vein is not quite fully included within the wing-stump, a small distal portion of it remaining outside. A true alula present in the form of a small rounded flap attached along a broad base at the base of the clavus, and folded completely under it. Venation almost complete, with branched Sc, many-branched R, M and Cu_1; R_1 and R_{2-3} simple, R_{4-5} with many anterior branches; anal veins obsolete and replaced by a very variable, indistinct and irregular meshwork, frequently obsolescent also.

Hindwing.—Wing-stump small, its length being less than one-sixteenth of the total length of the hindwing. No true wing-suture present, but the wing splits or tears off at a level slightly distad from the position of the free edge of the fore wing-stump in the position of rest (Text-fig. 7). A large anal lobe present, formed with the convex anterior branch of vein 2A as the anal fold; length of this lobe, measured along 2A, quite two-fifths of the total length of the wing. The anal lobe folds under the rest of the wing along the anal fold and may be strictly homologous with the alula of the forewing. Venation complete, with Sc simple or forked, R_1 and R_{2-3} simple and R_{4-5} with many anterior branches, as in forewing; but at its extreme base Rs is fused for a short distance with M; M and Cu_1 many-branched, Cu_2 simple or only forked distally. Anal veins well developed; 1A stout, with a series of irregular descending branchlets; 2A forked completely from base, the anterior branch lightly chitinized and forming the anal fold, the posterior branch with anterior branchlets; 3A with several branches arising from the third axillary.

Membrane of both wings thin and covered with a weak, irregular meshwork of veinlets, or archedictyon.

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EXPLANATION OF PLATE XXI.

Mastotermes darwiniensis Froggatt.—Enlarged photographs of fore and hind wings, from specimens dissected off with wing-stumps attached, and cleared and mounted in euparal.

Photographs by W. C. Davies, Cawthron Institute, Nelson, N.Z.

THE REACTION OF *VIMINARIA DENUDATA* TO INCREASED WATER CONTENT OF THE SOIL.

By LILIAN FRASER, B.Sc., Science Research Scholar in Botany, University of Sydney.

(Plate xxii; eighteen Text-figures.)

[Read 28th October, 1931.]

Introduction.

The observations given below are put on record in the hope that they may be of use in the interpretation of some of the anatomical peculiarities of marsh and water plants. A description is given of the reactions of the shrub, *Viminaria denudata* Sm., to a great increase in the water content of the soil in which it is growing; and also a brief consideration of the theoretical conclusions to be deduced from its behaviour.

Viminaria denudata Sm. belongs to the subfamily Papilionaceae of the Leguminosae. It is a switch plant attaining a height of about 12 feet. True leaves are present only in the juvenile stage, their function being early assumed by phyllodes which are terete, up to 15 inches long, and fairly firm but not rigid. It is interesting on account of the unusual degree of plasticity shown in its reaction to a change of environmental conditions. On the whole *Viminaria* requires a relatively moist soil for its best development.

In the Sydney (N.S.W.) district the geological formation is Mesozoic; three series of rocks, Narrabeen Beds (sandstone and shale), Hawkesbury Sandstone, and Wianamatta Shale, are present. In country where the soil is derived from sandstone rocks, *Viminaria* is limited, in most cases, to the banks of streams. But where the soil comes from weathered shale, and consequently has a higher water retaining capacity, *Viminaria* is often found in moderately sheltered positions remote from running water, even on slopes and hilltops. It is also quite commonly present along the margins of both freshwater and brackish swamps.

Some *Viminaria* shrubs which came under observation grew on the banks of a stream in sandstone country; the soil there was porous and usually damp, but not saturated. From 17th June to 5th July, 1930, steady rain fell, a total of 870 points being recorded. This caused the stream near which the *Viminaria* grew to overflow its banks, and the ground nearby became thoroughly saturated, and in places was under as much as six inches of slowly flowing water. The *Viminaria* plants remained in a flourishing state throughout the flooding. Their most conspicuous reaction to the change was the production by their roots, of short white breathing roots or pneumatophores. The photograph reproduced in Plate xxii, fig. 1, shows a small part of the flooded ground, and a number of the pneumatophores can be seen rising above the surface of the water amongst seedling plants and clumps of reed. Since then pneumatophores have frequently been observed on plants growing in temporarily saturated soils. The reaction to the flooding is very rapid, and recognizable pneumatophores may be produced in three or four days.

Viminaria may also show another feature characteristic of some marsh plants when its root system remains submerged for a week or more. This is the production of secondary aerenchyma. In the case of plants which grow near swampy ground, secondary aerenchyma is regularly developed. But it is important to notice that pneumatophores are not produced by these plants unless the soil is quite saturated.

General Description.

a. *Pneumatophores.*

1. Habit.

The root system of *Viminaria* is mainly shallow, whether the plant grows in moist or in wet soils. There are, as a rule, three or more main roots which grow practically horizontally at a depth of one to four inches below the surface of the soil. These roots give rise to branches of various sizes. The smaller ones ramify in all directions and are probably the main absorbing organs of the plant. The larger ones keep a more or less horizontal course, giving rise in their turn to smaller roots. Large *Viminaria* plants, especially those growing in well aerated, sandy soils, usually also have some deeply penetrating roots.

As previously stated, pneumatophores are produced by a root system of *Viminaria* when the soil in which it is growing becomes saturated. These pneumatophores are roots of spongy appearance and brittle nature, which develop from the beginning under almost aquatic conditions. In consequence they have, when mature, a structure quite different from that of roots which grow in well aerated soils. In habit they resemble to a remarkable degree the pneumatophores produced by some mangroves, though they lack the pneumatothodes present in those types.

Classified on their habit, the pneumatophores of *Viminaria* are of two kinds, (1) upright, and (2) "knee-bend"; and according to their mode of origin, the upright pneumatophores can be further divided into two classes, (*a*) primary, and (*b*) secondary.

For the production of a primary upright pneumatophore the growing point of a horizontal root turns and grows upwards above the surface of the soil or water. When there is a length of 0·5 to 6 cm. of root projecting into the atmosphere, growth ceases, the root-cap curls up and drops off, and various changes which will be discussed below, take place in the internal anatomy. The central pneumatophore (P) in Plate xxii, fig. 4, is a primary one, which has been broken off above the bend. Primary pneumatophores do not seem to be very common, the great majority of upright roots being secondary ones.

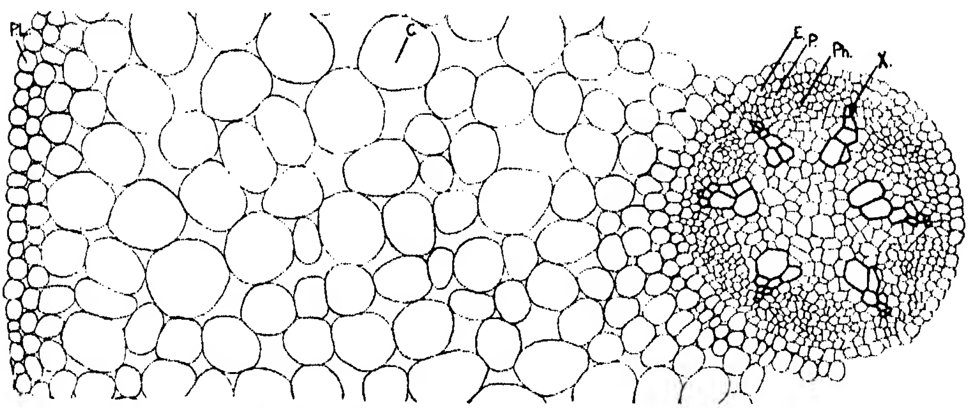
Submerged horizontal roots give rise to laterals corresponding to the absorbing roots of plants growing in damp soil. If these laterals arise from the under side of the root, they grow out and downwards, and act as absorbing roots (Plate xxii, figs. 2 and 3, A). But those which originate from the upper side grow vertically upwards into the air, forming secondary upright pneumatophores which are indistinguishable superficially from primary ones. Plate xxii, figs. 2, 3 and 5, show upright secondary pneumatophores arising from horizontal roots.

Mature pneumatophores occasionally produce lateral roots which also grow upwards into the atmosphere. This seems to be especially characteristic of the primary type. Plate xxii, fig. 4, shows the upper part of a primary pneumatophore with eight laterals growing up around it. In Plate xxii, fig. 5, the secondary upright root at the extreme right has produced one young lateral. Absorbing roots

are also occasionally produced at the bases of primary and secondary pneumatophores.

The upright pneumatophore functions for a week or longer after reaching its full size; it then begins to wither away from the tip (see upright pneumatophores in Plate xxii, fig. 2), but the part under water still remains alive for a variable time. Should the water level recede after flooding, the upright roots collapse and die, since their delicate and unprotected tissues are unable to withstand desiccation. If, on the other hand, the water level should rise still further after an initial flooding, a mature pneumatophore cannot grow and keep pace with it, having lost the power of apical development. Under such circumstances it may give rise to secondary pneumatophores which grow up above the new water level.

The second kind of pneumatophore, the "knee-bend" type, resembles in habit the breathing roots of the mangrove *Aegiceras*. It occurs exclusively as a modification of a horizontal root. Though by no means as common as the upright roots, this form is quite frequently met with, and seems to be commoner in saturated soils than water. For its formation, a horizontal root commences to grow upwards as if to form an upright root. But when it reaches the atmosphere, instead of continuing its upward course, the growing point turns and grows down again into the soil and there continues its original direction of growth (Plate xxii, figs. 2 and 3, K).



Text-fig. 1.—Transverse section of a young root which has developed in a saturated soil. P.L., piliferous layer; C, cortex; E, endodermis; P, pericycle; X, xylem; Ph., phloem. × 150.

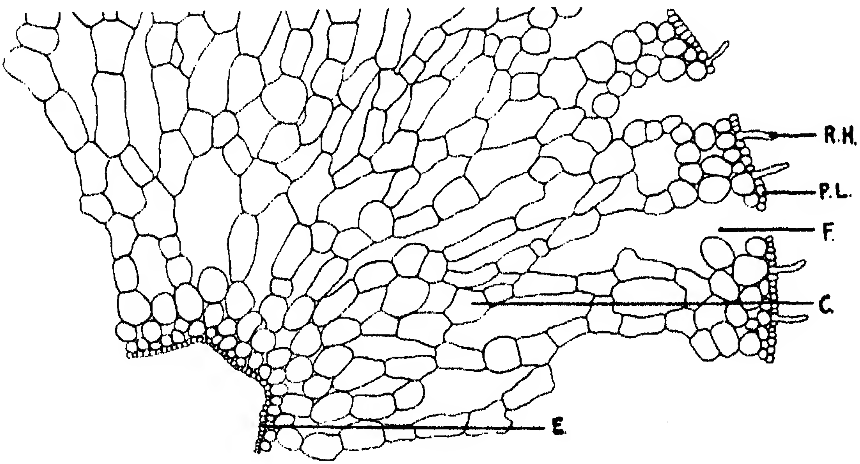
Several "knee-bends" are occasionally found close together on the same root, and it is a frequent thing for a horizontal root to give rise to both upright and "knee-bend" pneumatophores. Several cases were observed (Plate xxii, figs. 2 and 3) in which an upright pneumatophore grew out from the top of a "knee-bend". It is likely in this case that, after the formation of the "knee-bend", a second flooding submerged it and stimulated the development of the upright root.

ii. Internal anatomy.

Text-figure 1 shows part of the transverse section of a young upright pneumatophore at about the stage of the three at the left of Plate xxii, fig. 5. The structure is that of a typical dicotyledonous root. There is the usual central stele

with 4- to 9-arch xylem, an unthickened endodermis and a fairly wide primary cortex of large rounded cells. A noticeable feature of the cortex is the presence of an unusually well developed system of intercellular spaces, especially in the middle cortex. The piliferous layer and one or two layers of cells below it are composed of smaller cells, and this band forms a fairly compact region on the outside of the young root. A young absorbing root, and the first 2 to 6 centimetres of a horizontal root show, in transverse section, features essentially similar to those described for the young upright pneumatophore. Pneumatophores and horizontal roots subsequently become much modified, but an absorbing root retains this structure throughout its period of primary growth; only in one case was an absorbing root found which had developed a little aerenchyma at its base, and since this was similar to the tissue regularly developed by pneumatophores, it will not be described separately.

In sections of slightly older pneumatophores, it is seen that the cells of the cortex have increased to as much as three times their original diameter in a radial direction. The intercellular spaces between them increase in both radial



Text-fig. 2.—Transverse section of a young pneumatophore at a slightly more advanced stage than shown in Text-fig. 1. P.L., piliferous layer; R.H., root hair; F, fissure in tissue of cortex (C); E, endodermis. × 50.

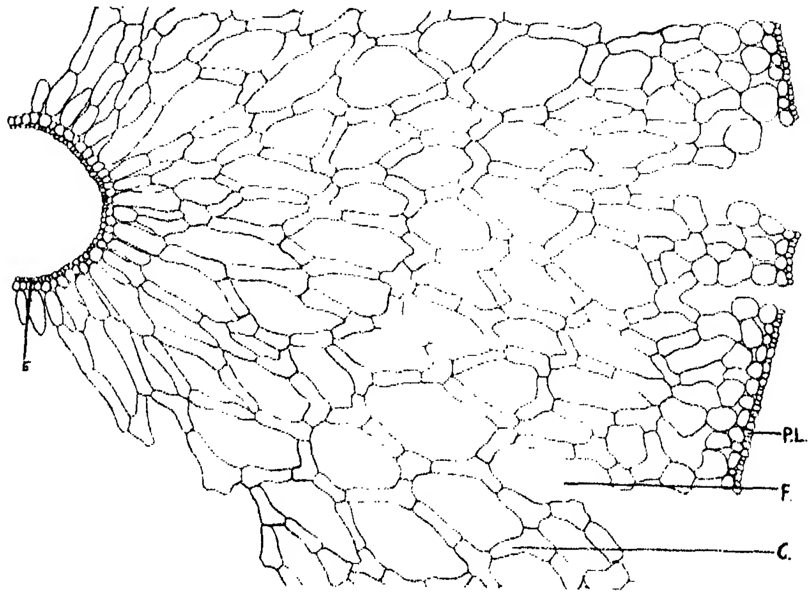
and tangential directions (see Text-figs. 2, 3). This increase is most marked in the middle cortex, where the cells pull apart and often assume X and Y shapes, with only the ends of the arms in contact. The cells of the compact outer layer do not increase much in size, and have evidently lost the power of division. This layer therefore becomes ruptured in numerous places by the pressure exerted by the extending cells below. These breaks often extend as fissures deep into the cortex. This process of aerenchyma formation proceeds gradually upwards from the base of a root towards the tip, and in mature pneumatophores air-spaces are present right to the apex, and the root-cap has broken away.

Text-figure 2 shows an early stage in the development of aerenchyma in the young pneumatophore, the cortical cells have begun to extend, and the intercellular spaces are already quite large. A number of narrow fissures (F) are

shown, and root hairs of a rudimentary appearance are present. A section 3·5–6 cm. from the apex of a horizontal root would show a structure similar to this.

Text-figure 3 is part of a transverse section of a mature pneumatophore; it shows the final stage in the development of primary aerenchyma in the cortex.

A mature upright pneumatophore is 0·5–1 cm. in diameter at its widest part, tapering towards the apex and often slightly towards the base also. Plate xxii, fig. 4, shows this feature well. In Plate xxii, fig. 5, the young pneumatophores on the left are still in the first stage of development, whilst the four at the right are



Text-fig. 3.—Transverse section of a mature pneumatophore. P.L., piliferous layer; F, fissure in tissue of cortex (C); E, endodermis. × 40.

mature and taper towards both base and apex. The horizontal roots remain of constant diameter (about 0·5 cm.), except towards the growing point, until the commencement of secondary growth (Plate xxii, fig. 5). The fissures seen in transverse section in the mature pneumatophore are visible externally as narrow slits of varying length (Plate xxii, figs. 3, 5).

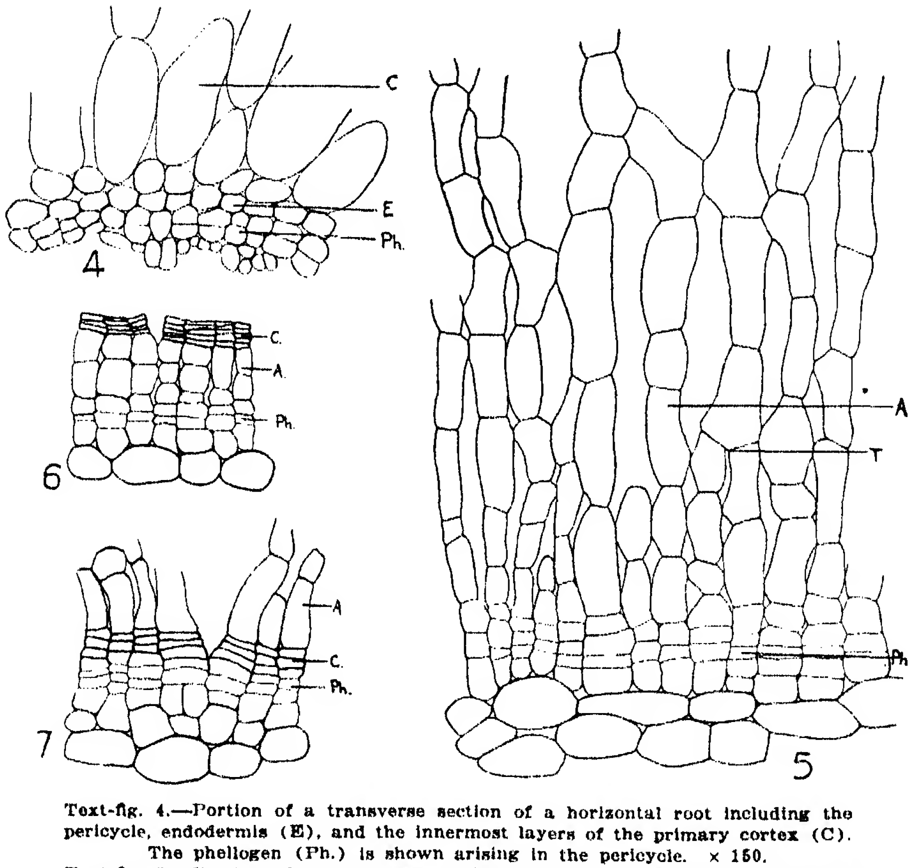
b. *Secondary Aerenchyma.*

The upright pneumatophores and the larger "knee-bends" undergo no further development and finally die away, but secondary growth takes place in horizontal roots, and in those producing "knee-bends" so short that they only reach the surface of the ground and do not come above it.

Soon after cambial activity commences in the stele, a phellogen arises in the cells of the pericycle. Text-fig. 4 shows the first divisions taking place in the pericycle. When the soil in which the root is growing is moderately dry, cork cells are cut off externally in the usual way. But when the ground is flooded, cells

are cut off externally whose walls remain unsuberised. These cells increase in length in a radial direction forming a secondary aerenchyma (Text-fig. 5, A). As a rule very little phelloderm is present, even in old roots.

As the central stele enlarges with the addition of secondary xylem and phloem, pressure is exerted on the phellogen. This pressure causes the cells of the phellogen to stretch in a tangential direction (cf. tangential diameter of the cells of the phellogen in Text-fig. 4 which is very young, with those in Text-fig. 5 which are much older) till finally the secondary aerenchyma cells cut off by them are not a great deal narrower than the cells of the primary aerenchyma. Once the cells of the phellogen have reached a maximum width, further increase in the size of the stele must be accommodated by tangential divisions in the phellogen.



Text-fig. 4.—Portion of a transverse section of a horizontal root including the pericycle, endodermis (E), and the innermost layers of the primary cortex (C). The phellogen (Ph.) is shown arising in the pericycle. × 150.

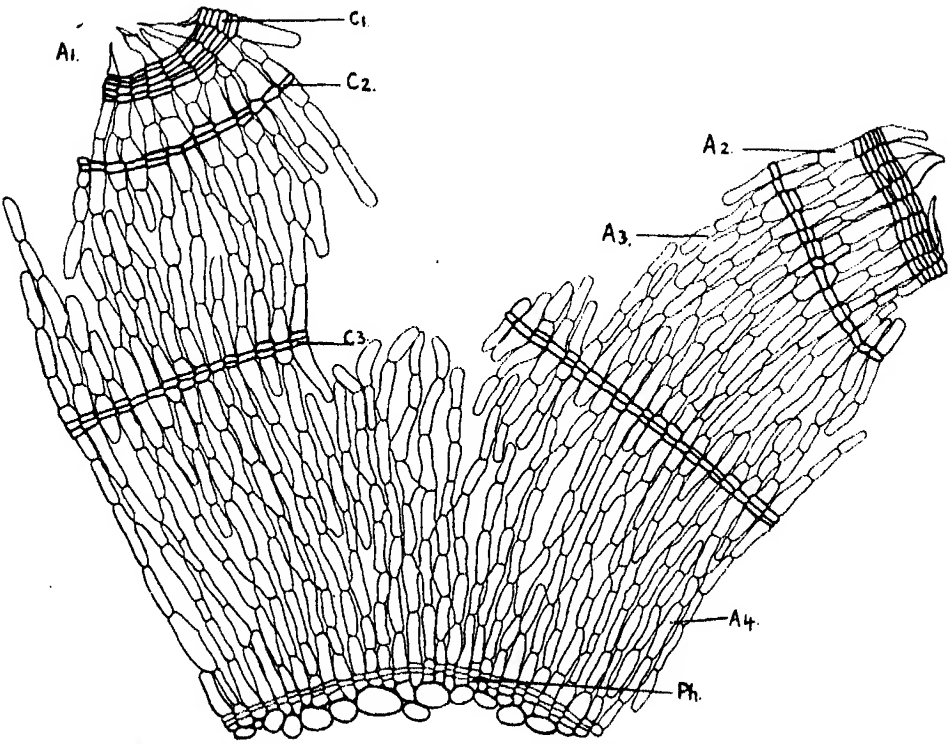
Text-fig. 5.—Portion of a transverse section of an old horizontal root showing the secondary aerenchyma (A), arising from the phellogen (Ph.). × 150.

Text-fig. 6.—Portion of a transverse section of an old horizontal root showing the development of secondary aerenchyma (A) below a layer of cork (C). Ph., phellogen. × 150.

Text-fig. 7.—Portion of a transverse section of an old horizontal root showing the development of a thick layer of cork (C) below secondary aerenchyma (A). Ph., phellogen. × 150.

The cells in Text-fig. 5 are of full size and there is evidence of a tangential division having taken place at T. The cells cut off externally by the phellogen evidently elongate at once in a radial direction with great rapidity. Evidence of this is found in the small number of cells intermediate in size between those of the phellogen and the aerenchyma.

The primary cortex and the outer secondary aerenchyma are pushed out, die and become brown, and fissures arise which are longer, deeper and more irregular than those of the primary pneumatophore. Usually they appear as winding furrows 3-5 cm. long; more rarely they are short and straight.



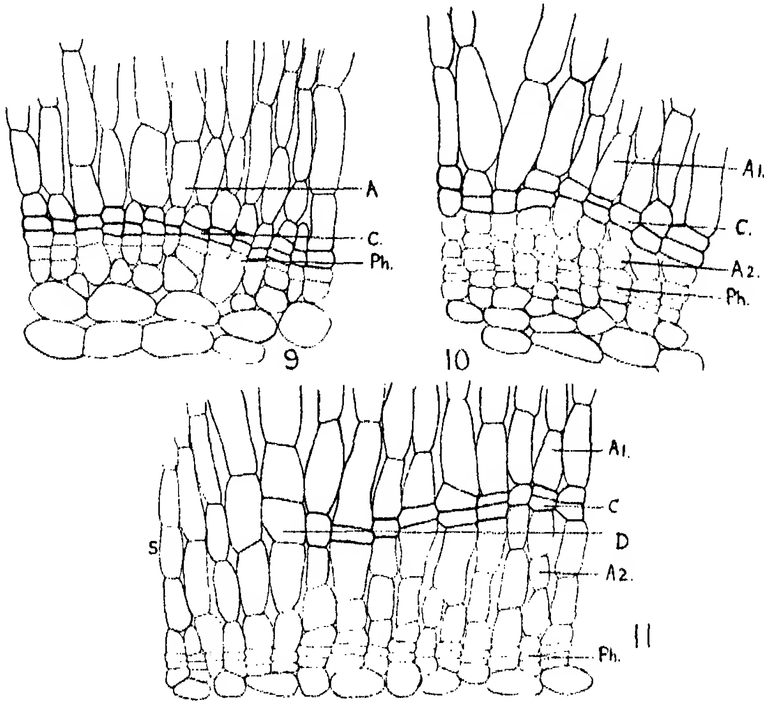
Text-fig. 8.—Portion of a transverse section of the periderm of an old root showing the development of successive rings of cork of varying widths, and a large fissure. C1, C2, C3, successive rings of cork; A1, A2, A3, A4, successive bands of aerenchyma; Ph., phellogen. × 40.

The cells of the secondary aerenchyma on the whole are slightly smaller than those of the primary cortex and, though they are arranged in regular rows end to end, there are fewer radial points of contact, so that the tissue as a whole is much less compact.

It is evident that the formation of aerenchyma is dependent on the saturated condition of the soil, since flooding induces the formation of aerenchyma in old roots which had already developed a layer of cork when growing under conditions of better soil aeration. Text-fig. 6 shows a band of cork being thrust outwards by the development of thin-walled cells below it. Then again, when the soil becomes relatively dry after flooding, a band of cork is formed in roots which previously

may have developed only secondary aerenchyma. In Text-fig. 7 the secondary aerenchyma is shown in the process of being cut off by a cork layer; it is in consequence brown and dead.

One feature of the aerenchyma of some of the large horizontal roots is of particular interest as evidence of the extreme rapidity with which the plant reacts to a change in its environment; a puzzling condition was met with in



Text-fig. 9.—Portion of a transverse section of the periderm of an old horizontal root. A cork layer (C) has just been cut off from the phellogen (Ph.). A, secondary aerenchyma. × 150.

Text-fig. 10.—Portion of a transverse section of the periderm of an old horizontal root, showing the formation of aerenchyma (A2) below a cork layer (C). Ph., phellogen; A1, old secondary aerenchyma. × 150.

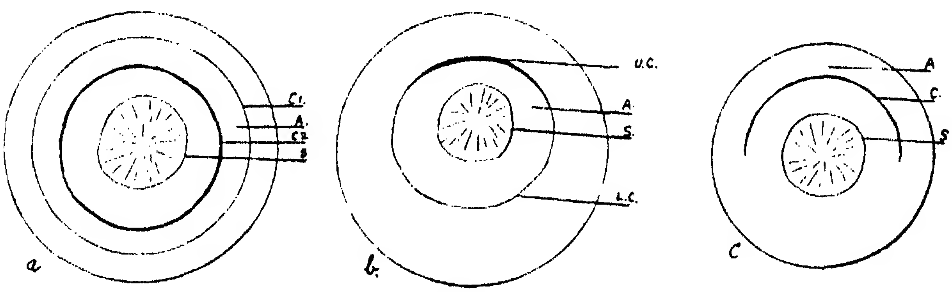
Text-fig. 11.—Portion of a transverse section of the periderm of an old horizontal root showing the abrupt ending off of a cork layer at D. S, under side of root; A, secondary aerenchyma; C, cork layer; Ph., phellogen. × 150.

sections of roots which had a large amount of secondary aerenchyma. At varying intervals the aerenchyma tissue was interrupted by layers of cork cells 1–8 or more cells in width (Text-fig. 8); their walls were evidently suberised, since they stained deeply in chlor-zinc iodine, strong caustic potash, and Sudan III. It is a very conspicuous feature that there is little or no gradation either in the size of the cells comprising the two types of tissue, or in the amount of suberisation of their walls. The transition from one type of tissue to the other is extremely abrupt.

Text-figure 9 shows a cork band which has just been cut off from the phellogen, and is already suberised. Text-figure 10 shows the resumption of aerenchyma formation after a band of cork has been formed; at this stage the previously formed aerenchyma is already dead. Text-figure 8 is part of a transverse section of a wide periderm, and it shows a number of interesting features. There are three cork layers in the part shown; C2 and C3 are narrow, but C1 is nearly as wide as the cork formed on roots which have developed from the beginning in well aerated soil. Moreover these three layers are placed at very uneven distances apart. The aerenchyma zone A4 is so wide that it is already beginning to die from the outside, while A3 is much narrower, and A2 is narrower still.

The distance between two cork rings is usually constant all the way round the root in any particular section (Text-fig. 12*a*), but occasionally one finds that the amount of aerenchyma between two cork layers is greater on the under side than on the upper, and where this is so, the part of the cork layer around the upper side of the root is slightly thicker than that around the lower side (Text-fig. 12*b*). The transition from the narrow to the wide part may be gradual or sudden. Text-figure 13 is part of a transverse section of some periderm tissue showing a sudden transition; cork is still being formed on the upper side of the root, while aerenchyma is still being cut off on the lower side (S). In Text-figure 10, S indicates the under side of the root; the cork layer C which is continuous over the upper half dies out at about D, and there is uninterrupted aerenchyma on the under side of the root (see also Text-fig. 12*c*).

The significance of these cork layers and their irregularities will be discussed later.

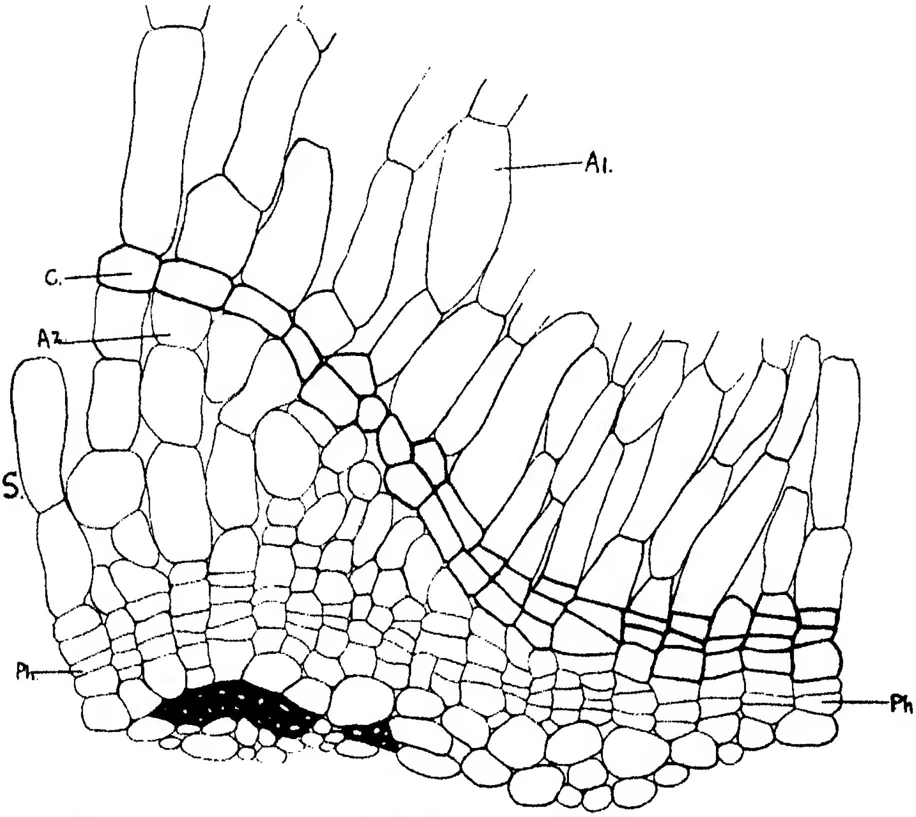


Text-fig. 12.—Diagrammatic representations of the transverse sections of old horizontal roots illustrating the development of cork rings. 12*a* shows concentric rings of cork C1 and C2 around the central stele (S); A, secondary aerenchyma.—12*b* shows a ring of cork which is much thicker on the upper side (U.C.) than on the lower side (L.C.). The aerenchyma (A) is thicker on the under side of the root, both inside and outside the cork ring. 12*c* shows a discontinuous ring of cork, over the top of the root only. These figures are, of necessity, much simplified.

c. *Bunches of Secondary Roots.*

Another feature probably to be associated with saturation of the soil is the development on young growing roots of bunches of secondary roots (see Plate xxii, fig. 4, S). They are usually found just below the level of the ground, sometimes pushing through to the surface, and a thorough search revealed their presence only in water-logged and submerged soil. They consist of many hundreds of small secondary roots which arise on a length of young growing root of

usually not more than 5 centimetres. They are thin and unbranched, with small growing points, and have numerous root hairs. The growth period of these roots is very limited; having attained their maximum length of about 2 centimetres they evidently function for a week to ten days and then die and rot away, leaving little trace on the exterior of the root which bore them.



Text-fig. 13.—Portion of a transverse section of the periderm of an old horizontal root showing the resumption of aerenchyma formation under a narrow band of cork (C) on the lower side (S) of a root, whilst cork is still being formed by the phellogen towards the upper side. Ph., phellogen; C, cork layer; A1, old aerenchyma; A2, newly formed aerenchyma. × 200.

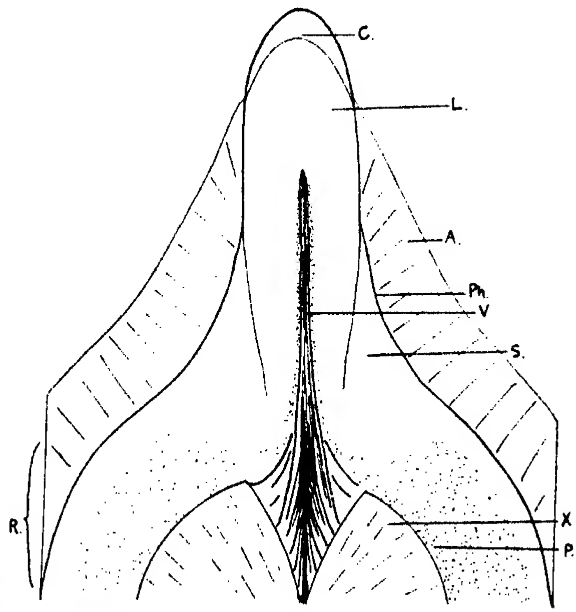
Their function remains obscure; it may be that they are organs of aeration similar in function to the pneumatophores, as their occurrence near to the surface of wet soil suggests. No trace of bacteria or fungi could be found in their tissues, and it is believed that their production is not due to stimulation by an endophyte.

d. *Bacterial Nodules.*

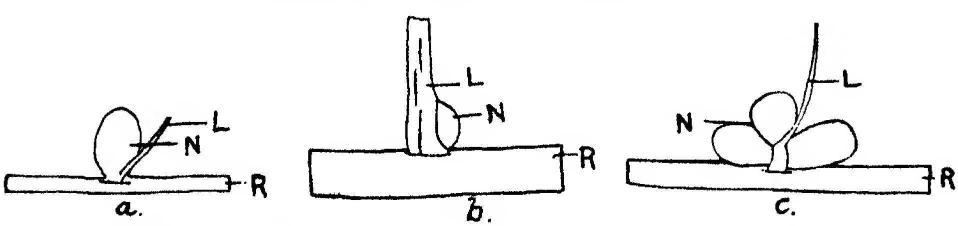
In *Viminaria* bacterial nodules arise in one of two ways.

(1). Frequently young lateral roots arise from old roots which have already developed a fairly thick periderm; in the neighbourhood of the young root the

phelloderm is very much wider than elsewhere. The periderm is pushed up round the young root as it emerges from the old root, and forms a collar 2–3 mm. high around its base. Text-figure 14 represents diagrammatically a transverse section through part of an old root showing the emergence of a young root and



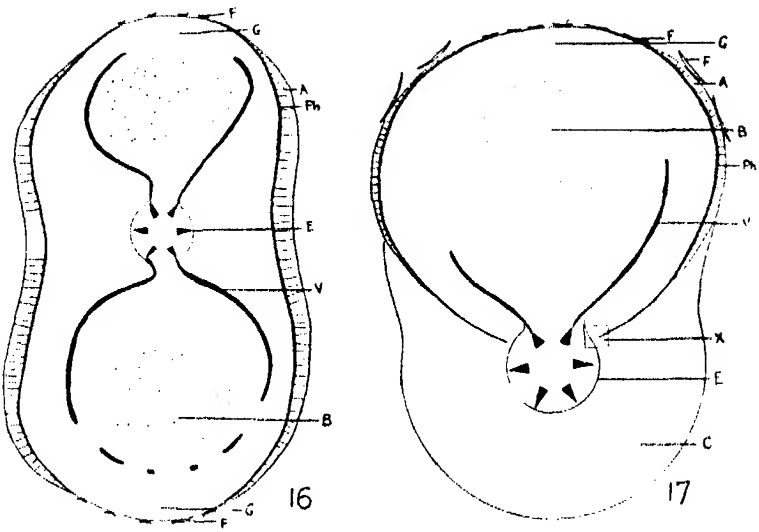
Text-fig. 14.—Transverse section of an old root (R) showing the departure of a young lateral root (L). X, secondary xylem of main root; P, phloem; Ph., phellogen; A, secondary aerenchyma; V, vascular strand of lateral root; G, root cap of lateral root; S, phelloderm.



Text-fig. 15.—Shows the formation of bacterial nodules (N) at the base of a lateral root (L). R, main root. *a*, *c*, × 1; *b*, × 2·5.

the upward extension of the periderm around it. A very usual place for bacterial infection is in the phelloderm of this upward extending region (S in Text-fig. 14); the actual point of infection is probably the cortex of the young root above the phellogen, and the infection thread of bacteria probably travels down from there into the phelloderm, since it is unlikely that infection could take place across a thick layer of aerenchyma which frequently includes bands of cork. A nodule then develops, covered from the beginning by an active phellogen which, under conditions of soil saturation, gives rise to an extensive secondary aerenchyma.

The nodule, very soon after its initiation, develops vascular strands which become linked up with the vascular tissue of the young root. Text-figures 15*a* and 15*b* show nodules at the base of young lateral roots, and Text-figure 16 shows diagrammatically a transverse section through the base of a young root which has two



Text-fig. 16.—Transverse section of the base of a young lateral root showing the development of two nodules within a common phellogen. V, vascular strands to nodules; E, endodermis; A, secondary aerenchyma; Ph., phellogen; F, isolated fragments of aerenchyma pushed out by the growth of the nodules; G, growing point of nodule; B, bacterial region.

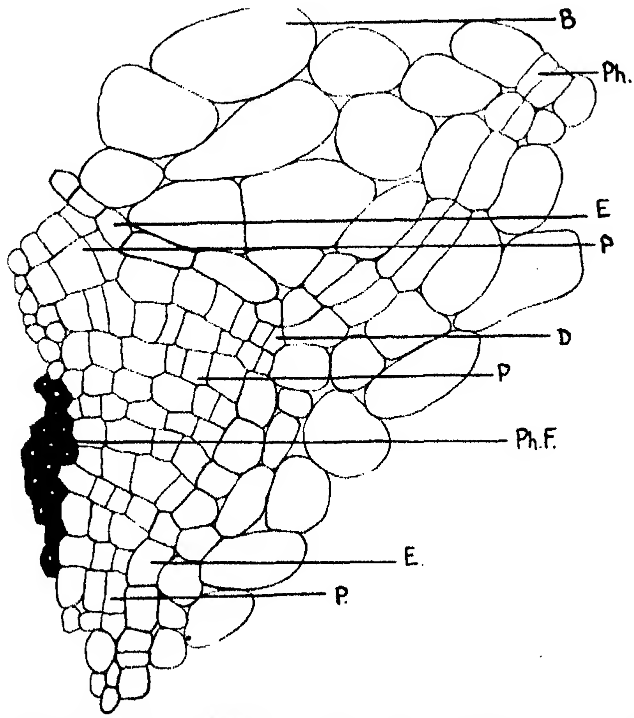
Text-fig. 17.—Transverse section of a young root, showing the second method of nodule formation. E, endodermis; A, secondary aerenchyma; Ph., phellogen of nodule; V, vascular strands to nodule; F, isolated fragments of primary aerenchyma; G, growing point of nodule; B, bacterial region; C, cortex of root; X, portion shown enlarged in Text-fig. 18.

nodules within a common periderm. In the region of the growing point of the young nodule the phellogen loses its characteristic appearance and grades into the meristem region which consists of smaller, more isodiametric cells.

Frequently, as shown in Text-figure 16, two or more nodules may commence to grow within a common periderm, and a large lobed nodule is finally formed at the base of the lateral root. This root never, apparently, reaches any great size, but soon dies back leaving a group of nodules whose mode of attachment to the root system is at first quite obscure (Text-fig. 15*c*).

(2). In the second case the bacterial nodule commences in the usual manner after infection of the cortex of a young root. Cortical cells in the neighbourhood of the endodermis divide rapidly, pushing back the outer cortex. Very early in the formation of a nodule, usually before it has burst through the cortex, the cells around its edges begin to divide at right angles to its direction of growth. These peripheral cells are already much elongated by pressure exerted by the dividing cells within, and the new walls are laid down along their greatest diameter.

In this way a peripheral cambium zone is formed which, as soon as the nodule is free from the cortical tissues of the parent root, cuts off a secondary aerenchyma outside it. This dividing tissue is best regarded as a phellogen. It extends gradually down to the endodermis of the parent root, and finally joins up with a pericyclic phellogen developing later in the root. Text-figure 17 shows how this is accomplished. A phellogen arising in the pericycle of the root cuts off a considerable tissue of thin-walled cells, pushing out the endodermis in a position just below the phellogen of the nodule; a few cells of the endodermis lying between the two then divide tangentially, joining up the internal and external phellogens. Subsequently formed aerenchyma then clothes root and nodule without a break.



Text-fig. 18.—Enlargement of square marked X in Text-fig. 17, to show the linking up of the phellogens of the root and the nodule by the division of endodermal cells at D, between the two. E, endodermis; Ph., phellogen of nodule; B, base of nodule; P, pericycle of root dividing to form a phellogen; Ph.F., phloem fibres. × 250.

There still exists in literature much doubt as to whether leguminous nodules are formed partly by the division of deep-seated cortical cells, or whether they are entirely intrastelic in origin. Thornton (1930) in a recent paper on the nodules of lucerne, expresses the opinion that both types are likely to occur.

It is undoubtedly the case in *Viminaria* that at least that part of the nodule external to the vascular strands is cortical in origin, because in young nodules whose phellogen has not yet joined up with that of the root, the endodermis can still clearly be seen, intact, below the cells composing the outer cortical region of the nodule (Text-fig. 18).

A feature of a great majority of the nodules of *Viminaria* is that the vascular strands arise from two or even three separate protoxylem poles of the parent root. This characteristic does not seem to have been reported for any other type of leguminous plant.

Discussion.

a. *Negatively Geotropic Roots.*

Clements (1921, p. 38), in a comprehensive summary of literature dealing with root growth, has come to the conclusion that the development of negatively geotropic roots is a type of aerotropic response by plants grown under conditions of poor soil aeration due to the high water content.

Cases of such root development are by no means rare: numbers of plants habitually develop pneumatophores; others which normally grow in well aerated soil, do so when the soil is saturated. The mangrove vegetation, which grows in saline, airless mud, includes the classic and most consistently pneumatophore-producing types. *Sonneratia* and *Avicennia* (Goebel, p. 278) produce such upright breathing roots; others, *Aegiceras* for example, have "knee-bend" pneumatophores. The phenomenon is not limited to Angiosperms: the Gymnosperm *Taxodium distichum*, when growing in saturated soils, develops short club-like upgrowths and "knee-bends" which are supposed to serve as breathing organs. In the foregoing examples the roots are fairly stout structures with an extensive development of secondary wood.

Jost (1887, p. 601) describes the much less massive negatively geotropic roots produced by *Cyperus*, *Richardia*, *Musa*, and *Papyrus*, when grown in glasshouses, and believes that such breathing organs are widely distributed in the plant world. Several species of *Jussiaea* are also known to produce aerotropic rootlets.

Other plants which do not produce definite pneumatophores, e.g., *Alnus* and *Fraxinus* develop instead an abundance of fine much branched roots near to the surface of the soil (Jost, 1887). Lately Weaver and Himmel (1930) have found that in water-logged soils, such marsh plants as *Scirpus nodosus* and *Typha latifolia* develop a large number of similar roots which grow upwards to the surface of the water, and there spread out widely and often branch profusely.

Nothing is definitely known concerning the mechanism of aerotropic response; as yet one can only postulate that the absence of oxygen in some way overcomes the action of those stimuli which produce the characteristic geotropic and negatively heliotropic responses of most roots.

b. *Aerenchyma.*

A feature of the anatomy of breathing roots is the production of aerenchyma in their cortical regions. In fact, practically all plants growing under aquatic or semi-aquatic conditions show an extensive development of air spaces; and it is important to note that where there is a species or variety sufficiently adaptable to grow both on unsaturated land and under semi-aquatic conditions, in the latter case there is a much greater development of aerenchyma (Arber, p. 201).

There are two main types of aerenchyma, and between them all possible intergradations are found (Arber, ch. xiv; Haberlandt, p. 441). In the first type the component cells are stellate with air spaces between the arms, in the second type the air spaces are developed between plates of rounded or rectangular cells.

In *Viminaria* the aerenchyma is of an intermediate variety; the cells often show short arm-like prolongations, but the lamellar condition is also approached.

Again we are uncertain why there should be this reaction to conditions of more than adequate soil moisture and less than adequate soil oxygen. In this connection, it is of interest to note that Andrews and Beals (1919) in water culture experiments with *Zea mais* found that the roots of plants growing in unaerated media showed a greater development of intercellular spaces than those which grew in aerated media. This seems to point to diminished oxygen supply as being the important factor in the formation of air space systems.

c. *Secondary Aerenchyma.*

Secondary aerenchyma has been described in species of *Jussiaea* and in several leguminous plants, *Neptunia oleracea* and *Sesbania.* Scott (1888) has described the secondary aerenchyma developed by the aquatic roots of *Sesbania aculeata* as arising from a phellogen which originates by the division of cells immediately outside the endodermis, the first or second row of cortical cells. In *Viminaria* the phellogen originates in the normal fashion in the pericycle, and the endodermis is thrown off, together with the primary cortex, on the development of secondary tissue.

Normally the walls of cork cells become impregnated with suberin soon after they are cut off from the phellogen.

Priestley and Woffenden (1922) have come to the conclusion that the preliminary suberisation of cork cell walls is dependent on the presence of air; their experiments show that at least one of the constituents of suberin, phellonic acid, can be taken into solution readily enough, thus preventing suberisation of cell walls in contact with water.

When phellogen activity takes place in a root of *Viminaria* it would appear likely that some of the constituents of suberin go into solution in the surrounding water, and the cell walls of the secondary tissue remain of unimpregnated cellulose and are therefore extensible. If, for a short while, the water level fell and the environment were temporarily drier, the fatty acids released from the protoplasm of the young cork cells would undergo condensation in the absence of an excess of water, and cork layers of varying width would be formed according to whether the period of dryness were long or short.

This explanation gains support from the irregularity with which the layers of cork sometimes arise. When, for instance, a ring of cork is thicker, and at the same time nearer to the phellogen on the upper side of a horizontal root than on the under side, and at the same time the aerenchyma of the ring outside the cork band is wider on the under side, that would indicate a slow fall in water level affecting first the uppermost phellogen derivatives and gradually extending its effect round to the lower ones. If the ring of aerenchyma within the cork band were thicker on the under side, that would indicate a slow rise in water level causing the formation of aerenchyma first on the lower side and then on the upper side of the root. Text-figure 13 indicates that an abrupt rise took place in water level to L, with consequent formation of aerenchyma in the lower part while in the upper part cork formation is still going on. The fluctuations in water level which would be necessary to produce these changes would be quite small.

These results as thus interpreted lend support to Arber's statement (p. 194) that the structure of secondary air containing tissues "is directly induced by environmental conditions, and their serving any purpose is to be regarded as quite fortuitous".

SUMMARY.

1. *Viminaria denudata* Sm., a leguminous shrub growing normally in fairly well aerated soils, can survive a condition of soil saturation for extended periods; it reacts to these conditions in definite ways: *a.*—By the production of both upright and "knee-bend" pneumatophores or breathing roots, in whose parenchymatous tissue an extensive aerating system is present. *b.*—By the production of a secondary aerenchyma in submerged roots which is cut off from a phellogen arising in the pericycle, replacing the cork layers of the normal root.

2. Bacterial nodules may also have a covering of secondary aerenchyma except at their growing points. A nodule may arise in one of two ways: *a.*—By the infection of secondary cortical tissue which is pushed up in a collar round the base of a young lateral root where it arises from its parent root. In this case the nodule is covered from the beginning by a secondary aerenchyma developed from the phellogen of the old root. *b.*—Normally by infection of the cortex of a young root. In this case a phellogen arising round the periphery of the growing nodule becomes continuous with that of the parent root by division of endodermal cells in a position just below the phellogen of the young nodule.

3. Occasional rings of cork of varying width may occur between the zones of secondary aerenchyma in the secondary tissue developed from the phellogen; these are believed to be formed during periods of relatively less soil saturation.

In conclusion, I wish to thank Professor Osborn, of the Department of Botany, University of Sydney, for the interest he has shown during the progress of the work, and for his helpful criticism.

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EXPLANATION OF PLATE XXII.

Fig. 1.—Upright pneumatophores of *Viminaria denudata* growing under natural conditions.

Figs. 2, 3.—Horizontal roots with "knee-bend" pneumatophores (K), upright secondary pneumatophores (P), and absorbing roots (A).

Fig. 4.—Upper part of a primary upright pneumatophore (P), with lateral pneumatophores (P.L.), and young bunches of secondary roots (S).

Fig. 5.—Horizontal root with upright secondary pneumatophores (P), of which the three on the left are the younger, the pneumatophore on the extreme right has given rise to a young lateral (P.L.).

Fig. 1 × ¼ approx.; figs. 2-5 × ½.

NOTES ON AUSTRALIAN MARINE ALGAE. VI.

Descriptions of Six New Species.

By A. H. S. Lucas, M.A., B.Sc.

(Plates xxiii–xxvii.)

[Read 28th October, 1931.]

Gelidium rectangulare, n. sp. Plate xxiii, fig. 1.

Gelidium, caule compresso distiche pinnate decomposito, ramis bipinnatis elongatis; pinnulis rectangulariter emergentibus a margine pinnae, oppositis pectinatis linearibus rigidis, a marginibus foliola tetrasporangifera minuta seriata ferentibus. Caulis filis interioribus dense farctus. Color obscure purpurascens.

Base scutiform, disk with a plexus of lobes spreading over the rock surface.

Stem compressed, about 2 mm. wide, naked in lower third or with scattered irregular branchlets, above with long spreading distichously spreading branches. Height of plant to 30 cm. or more. Rami flat distichously bipinnate. Ultimate pinnules numerous, opposite, pectinate, arising from the margins of the pinna at right angles, rigid, about 5 mm. long, linear, more or less obtuse.

Tetrasporangia scattered over median area of tiny folioles springing in series from the margins of the ultimate pinnules. Folioles distinctly pedunculate irregularly ovate-oblong, not longer than the diameter of the pinnule.

Stem composed of two layers, the inner three-fifths of fine colourless fibres, longitudinal and oblique, densely packed, including in the meshes occasional coloured cells and granulated branches, the outer of densely packed rounded coloured cells in more or less regularly vertical series, the outermost minute.

Colour dark purpurascent.

Structure rigid cartilaginous. Does not adhere to the paper.

Habitat.—Flinders Bay near Cape Leeuwin (Lucas) and Point Le Hunt, and Clare Bay at the head of the Great Australian Bight (Dr. G. A. Chambers).

In the absence of plants bearing cystocarps one has to rely on the habit in assigning this species to *Gelidium* rather than to *Pterocladia*. Both genera occur in Australian waters.

At first I thought that I had in hand plants of *G. asperum* (Mert.) J. Ag. I sent specimens to Prof. H. Kylin, who courteously compared them with those so labelled in the Agardhian Herbarium at Lund. He has informed me that "it is not at all *G. asperum* J. Ag., which has quite another habitus. I think it to be a new species."

The habitat of the genuine *G. asperum* (Mert.) J. Ag. seems to be somewhat mysterious. De Toni gives "In oceano Australi ad Novam Hollandiam (Labillardière); ad 'Port St. Philippe' (Malm); ad Novam Zelandiam (Baume)." There are no examples of it in the Melbourne Herbarium, which contains Sonder's Herbarium and Bracebridge Wilson's collections, nor have I ever seen it on my own collecting expeditions. R. M. Laing does not admit it into his Reference List of New Zealand Algae, and writes me that he knows nothing of it in New Zealand. Can it be, as De Toni suggests, a form of *G. glandulaefolium*? He says: "Planta

fertilis in parte sterili nullos denticulos offert sed partes inermes etiam in sterili planta adsunt. Fertilis ad *Gelidium glandulaefolium* summopere adproximatur nisi cum eo eandem speciem sistit."

PTEROCLADIA PECTINATA, n. sp. Plate xxiii, fig. 2.

I forwarded sterile examples of this plant to Mrs. E. S. Gepp of the British Museum, and it was described in the *Journal of Botany*, 1906, by A. and E. S. Gepp. In my notes accompanying the specimens I wrote "Only obtained from deeper water when cast up by storms. I am inclined to put it down as a deeper growing, vegetative form of *P. lucida*. As far as I can make out, the structure of the frond is similar." This view was accepted by the Gepps, and the plant described by them as *Pterocladia lucida* (R. Br.) J. Ag.

"Forma *pectinata*, f. nov. Fronde compressa anguste elongata disticha a basi pectinato-pinnata (alioqui parce ramosa ramis pectinatis) ramulos copiosos patentes lineares acuminatos inter sese spatiis latitudini eorum aequalibus separatos gerente."

Having some years later gathered plants in the same locality bearing cystocarps, I would add to the above

frondibus cystocarpiferis sterilibus similibus, pinnulis cystocarpia terminalia ferentibus

and the whole will constitute the description of a new species, *Pterocladia pectinata.*

These cystocarps are quite unlike those of *P. lucida*, which are formed in the middle of the pinnules, while those in this form are terminal.

The cystocarps, too, of *P. pectinata* contain large spores, while those of *P. lucida* enclose much branched slender gonimoblastic threads bearing at the extremities of the branches minute spores. Hence it seems necessary to give to this "form" the status of a distinct species.

My idea that the elongated slenderer plants were vegetative was disproved by the occurrence of plants distinguishable from the sterile plants only by the presence of numerous, all terminal, cystocarps.

Habitat.—Maroubra Bay on an ocean beach between Port Jackson and Botany Bay. Found by me cast up in the month of July, 1901 and 1910.

Professor Kylin, to whom I recently sent an example, writes me: "Your *Pterocladia lucida*, I think, is better to describe as a new species. In J. G. Agardh's Herbarium there is a specimen which quite agrees with yours, but this is labelled as a variety of *Pt. lucida* and does not look like the type forms."

NITOPHYLLUM (MYRIOGRAMME?) PERRINAE, n. sp. Plate xxiv.

. Stipites gregarii, e disco parvulo surgentes, robusti, subcylindracei sensim compressi, mox in 2–6 ramos primarios abeuntes. Inferior pars rami, ut in stipite, nuda, robusta, sensim compressa, in folium transiens, vel in duo pluresve similes ramos secundarios ipsos in folia transientes divisa. Folia ad 12 cm. alta, 4 ad 10 cm. lata, late ovata, querciformia, undulata, profunde lobata, tenuiter membranacea. Apices loborum rotundata, obtusa; margines integri vel irregulariter minute dentati; costa prominens nervos validos pluries subdivisos in membranam mergentes emittens; membrana plerumque monostromatica. Cellulae membranae subaequales pentagonales, nervorum elongatae rectangulares. Neque cystocarpia nec tetrasporangia adhuc visa. Frons ad 15 cm. altus. Color roseus.

Attachment.—Plants growing in clumps, each stipe with an unexpanded simple disk at the base.

Stipes.—Stout, subcylindrical, gradually compressed, 8–11 mm. long, to 3 cm. broad, soon dividing into 2–6 divergent primary rami.

Rami.—Primary stout, similar to stipes, becoming gradually compressed, the lower 3 cm. naked, then forming a foliar expansion or again dividing into two or more flattened secondary branches. Each ultimate branch passes sensibly into an ovate folium.

Frond.—Folia to 12 cm. long, 4 to 10 cm. wide, broadly ovate, querciform, deeply lobed with undulate borders, thin membranaceous, of a rose-carmine colour. Apices of lobes rounded, obtuse. Margins nearly entire or with small irregular teeth. Midrib tough, broad below, narrowing upwards, flesh-coloured, giving off numerous nerves or branches which continue to subdivide by alternate not dichotomous branching, the ultimate divisions merging in the membrane. Cells roughly pentagonal, those of the nerves elongate rectangular.

No cystocarps or tetrasporangia seen. Height of plant to 15 cm.

Habitat.—Growing on rocky bottom at 4–8 fathoms in the River Tamar, near Georgetown. Gathered in January by Mrs. F. Perrin and A. H. S. Lucas.

Dedicated to my co-worker, Mrs. F. Perrin, of Launceston, Tasmania.

CHAMPIA INSIGNIS, n. sp. Plate xxv, fig. 1.

Frondes singulae vel plures ad lapillos et conchas disco lobato affixae, in circuitu late ovatae, compressae, bi-tri-pinnatae.

Rachis primaria basi valde attenuata, in medio expansa, sensim in apicem obtusiusculam attenuata, per totam frondem conspicue persistens, ad 18 cm. longa, ad 5 mm. lata.

Rami primarii basi tenuiter pedunculati, compressi, disticho alternantes, 5–6 mm. distantes, in apicem minus obtusam attenuati. Dissepimenta conspicua; articuli diametro breviores, ramulosum subaequales, ad genicula, nisi plantae fructiferae, haud conspicue constricti.

Cystocarpia supra paginas sparsa. Tetrasporangia triangule divisa, numerosa, sparsa, circ. 80 μ diametro. Antheridia invisa. Color laete purpureus. Substantia gelatinoso-succosa: planta ad chartam arcte adhaeret.

Hab. in aestuario fluminis Derwent Tasmaniae, in mense Octobri.

Fronds growing singly or in clusters attached to pebbles or shells by a lobed disk; of a broadly ovate outline, compressed, bi-tri-pinnate, the main rachis conspicuously persistent.

Rachis attenuated at base, expanding and then contracting again less markedly to the rather obtuse apex. Length to 18 cm., breadth to 5 mm.

Primary branches alternate, distichous, 5–6 mm. distant, with a thin linear peduncle, expanded in the middle and slowly tapering to a more pointed apex.

Length to 10 cm., breadth 3–5 mm. Length of secondary branches to 2 cm.

Dissepiments conspicuous. Joints of rachis and primary branches shorter than broad, of secondary about as long as broad, not conspicuously constricted at the genicula, more obviously so in fruiting plants.

Cystocarps scattered on the faces of the secondary branches, not numerous in plants seen. Tetrasporangia triangularly divided, scattered abundantly over the secondary and tertiary branches.

Colour a bright purple. Substance gelatinous succose; plant adheres closely to paper.

Habitat.—Estuary of the River Derwent, Tasmania. Gathered in the month of October.

The species is distinguished from *C. tasmanica* by the much larger scale of the parts, its more open spacing and the bright purple colour.

LESSONIA CORRUGATA, n. sp.

Stipes inferne subteres, mox complanatus, superne planus, plerumque sexieno dichotome ramosus, infra dichotomias cuneatim dilatatus, ramulis ultimis laminas geminatas ferentibus. Vesiculae nullae. Laminae planae angustae praelongae lineari-ensiformes, inferne superneque attenuatae, conspicuis costis rugulosae, margine aculeis alternis robustis munito. Color olivaceus.

A robust bushy plant with strong scutiform attachment growing in association with *Macrocystis* on a rocky bottom. The stipes, not stouter than the little finger, subterete below but soon becoming compressed and then broadening and flat, subdividing by some half-dozen dichotomies, the last branches splitting into twin laminae. There is a cuneate widening of the stem below each dichotomy. There are no vesicles. The laminae are attenuated at each end, 3 feet or more long, and less than an inch wide, linear-ensiform, the surface conspicuously rugose with parallel longitudinal ribs, five or more in number, running the length of the frond, and the margin furnished with alternate stout flattened hooked aculei, 5 mm. long, with broad bases. The colour olive, often with a greenish tinge.

No *Lessonia* has been hitherto recorded from Australia or Tasmania. Our species is quite unlike the New Zealand species *L. variegata* J. Ag. Mr. R. M. Laing, to whom I submitted a specimen, writes me: "We have nothing like it." Our plant differs from all others previously described by the strongly ribbed surface and the well-developed stout marginal prickles.

I obtained the plant by dredging in 4–5 fathoms in Port Arthur, and gathered younger ones in deep rock pools at Southport. It probably occurs all round the South Coast of Tasmania.

CAULERPA ANNULATA, n. sp. Plate xxvii, fig. 1.

Frondes a surculo repente, continuo, glabro, satis robusto nec rachidibus crassiore, erectae.

Rachides ad 17 cm. altae, simplices vel semel bisve furcatae, 3–4 mm. crassae, omnino a basi ima annulato-constrictae, glabrae. Segmenta ramentis geminis subapice surgentibus, disticha positis, a basi induta.

Ramenta lineari-cylindracea, 7–9 mm. longa, diametro circiter 3 mm., sessilia basi constricta, apicibus rotundis obtusissimis, glaberrima, obscure viridia.

Surculus continuous, terete, rather stout but not thicker than the rachides of the assimilators, of the thickness of a crow's quill, quite glabrous.

Assimilators erect to 17 cm. high, simple or once or twice forked, with a tendency to give off rooting branches, as is the case with *C. cactoides* and *C. Fergusonii*, the rachides about 3·5 mm. thick, glabrous, from the very base regularly annulate-constricted into segments as broad as long with rounded contours, bearing distichously pinnate ramenta.

Ramenta rising from just below the apex of each segment, geminate, linear-cylindrical, 7–9 mm. long, about as broad as the rachis, with round, blunt, scarcely dilated apices, constricted at the base, all conspicuously glabrous and dark green.

The species clearly belongs to the Section *Cactoideae*, with *C. cactoides*, *C. Hodkinsoniae* from the Richmond River of northern New South Wales, Harvey's

C. articulata (Pl. xxvii, fig. 2) from the eastern coast of the North Island of New Zealand and G. Murray's *C. Fergusonii* from Ceylon.

It differs from *C. cactoides*, widely distributed in the southern half of Australia and in Tasmania, in the magnitude of the parts, the rachides not naked at the base, the conspicuously distichous habit, and the linear not clavo-obovate ramenta.

We have no examples of J. Agardh's *C. Hodkinsoniae* in Australian Herbaria. He, however, describes it as decompound-branching, the joints cylindraceous, 3-4 times longer than the diameter, and the ramenta cylindraceous-clavate and subpetiolate.

I thought at first that the plant might be identical with *C. articulata*, a species collected but only rarely in New Zealand, but Mr. R. M. Laing very kindly loaned me a fine specimen, and later procured another for me from Lyall Bay. In these the surculus is very slender and the whole plant more delicate than ours, the joints are not rounded but linear, somewhat dilated anteriorly, and the colour a light green. To illustrate the differences, Plate xxvii shows photographs of the two species side by side.

C. Fergusonii, figured and described by Murray (*Trans. Linn. Soc. London*, 1891), has ovate ramenta, rhachis terete below, and a stout surculus. It is much more closely related to *C. cactoides*, and has, in fact, been regarded by Grunow as a smaller variety of that species.

The plant has been found so far only in the outer waters of Port Arthur. Mrs. Perrin and I dredged a fragment in 5 or 6 fathoms in February. Other specimens were obtained for me in the same locality by Mr. E. Mawle in September. Like *C. articulata*, it appears to grow only in water of moderate depth.

I take the opportunity of giving photographs of three species not heretofore figured:

Caulerpa cliftoni Harv. (Plate xxv, fig. 2), identified with *C. Abies-marina* J. Ag. by Madame Weber van Bosse, from Pt. Lonsdale, Victoria.

Dictyota bifurca J. Ag. (Pl. xxvi, fig. 1) and *D. alternifida* J. Ag. (Pl. xxvi, fig. 2), from named specimens in the National Herbarium, Melbourne, by the courtesy of the Director.

EXPLANATION OF PLATES XXIII-XXVII.

Plate xxiii.

1.—*Gelidium rectangulare*, n. sp.
2.—*Pterocladia pectinata*, n. sp.

Plate xxiv.

Nitophyllum Perrinae, n. sp.

Plate xxv.

1.—*Champia insignis*, n. sp.
2.—*Caulerpa Cliftoni* Harv. = *C. Abies-marina* J. Ag.

Plate xxvi.

1.—*Dictyota bifurca* J. Ag.
2.—*Dictyota alternifida* J. Ag.

Plate xxvii.

1.—*Caulerpa annulata*, n. sp.
2.—*Caulerpa articulata* Harvey.

The dimensions are given by the side scale of 3 cm.

THE PHYSIOGRAPHY OF THE SHOALHAVEN RIVER VALLEY. IV.

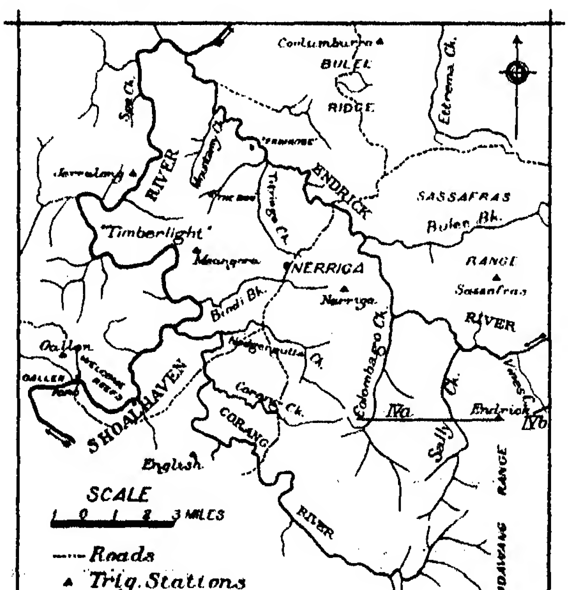
NERRIGA.

By FRANK A. CRAFT, B.Sc., Linnean Macleay Fellow of the Society in Geography.

(Plates xxviii–xxix; four Text-figures.)

[Read 28th October, 1931.]

Foreword.—This paper is designed to give a detailed physiographic survey of an area where horizontal and folded rocks exist side by side under varying conditions, and to determine their relationship to the land forms developed. The physiographic history of part of the tableland is further dealt with, and it has been possible to date the various features with reference to late Tertiary basalt. This should be of assistance in areas of a similar type where such a key is not found. The magnetic meridian (trigonometrical survey declination 9° 30′) is used in the text and maps, which are based on the parish and county maps kindly supplied by the Lands Department.



Text-fig. 1.—Map of the Area, showing the principal names used. See also Plate xxviii.

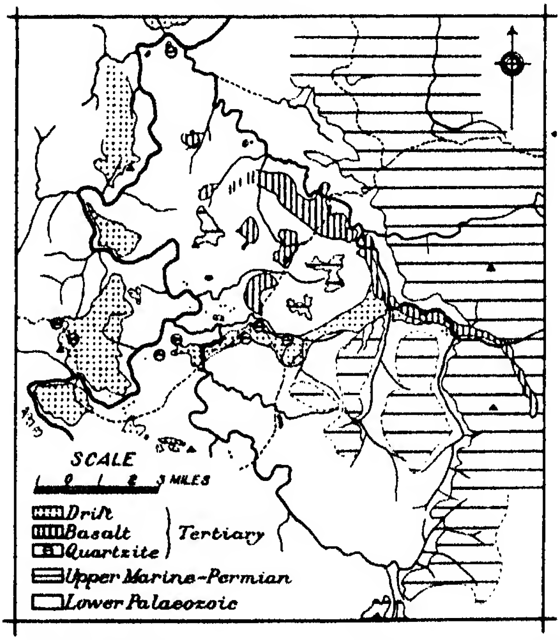
The Area Dealt With. Text-figs. 1 and 3.

When standing on one of the clear hills near the head of Corang River, an observer may see the area described in this paper to be part of a wide upland plain

stretching far to the west until it is broken by long meridional ridges, which are vague and shadowy in the distance. The Shoalhaven River flows over this tableland to plunge into the gorges of its lower course. Eastward, the plain rises into irregular ridges and buttes which, in their turn, give place to the even heights of Bulee Ridge and its southern extension—Sassafras Range. The higher areas form the crest of a tilted plain which rises from the coast; the eastward slope is a wilderness of narrow ravines carved by tributaries of the Clyde and lower Shoalhaven Rivers, but these lie beyond the scope of the present enquiry, which is concerned with the westward fall from the coastal highlands and with part of the great upland plain.

Geology and Resistance to Erosion. Text-fig. 2.

The geological features which have been noted in the earlier papers of the series continue into this area, although their relative extent and importance are found to change as one goes southward. For example, the horizontal Permian



Text-fig. 2.—Geological Sketch of the Area. Devonian beds probably occur in the south-east of the portion marked "lower Palaeozoic".

sandstones have determined many of the physical features of the Nerriga district, but they end against the northern flank of Currockbilly Range, which is formed of older quartzites. A general physiographic classification may be made on the basis of age, as follows:

Tertiary.—There is a considerable extent of stream gravels and drift between 1,650 and 2,050 feet. As in the Nerrimunga Creek area, these deposits fill valleys which had been eroded in the upland (Shoalhaven) plain, and they extend over part of that surface in the vicinity of the main stream. The more northerly occur-

rences are similar to those which have already been described, but southward one finds the fine clays replaced by grit, and grits by pebble beds. Included in the series are clays containing plant remains, presumably of late Tertiary age, but it has not yet been possible to have a determination made.

Basalt flows have been associated with the drifts, and considerable portions of them remain in the valley of Endrick River, whence they extend over low parts of the sub-divide on to the Corang drainage area. There the past extent is indicated by the presence of grey contact quartzites, which are found scattered over the sandy uplands between 1,900 and 2,060 feet. The disappearance of so much basalt can be attributed to pre-erosional weathering and the removal of soluble products after erosion of the more recent valleys and gorges had commenced. The hard and chemically inactive quartzites survive the basalt, and in places protect the friable drift which underlies them. Much of the late Tertiary landscape is still in a good state of preservation.

Permian.—The Upper Marine Series is present in the eastern part of the area; it consists of light grey and reddish sandstone with occasional bands of conglomerate and erratics, and rests on layers of agglomerate, heavy conglomerate and breccia. The strata are almost horizontal and have a maximum thickness of 700 feet between Bulee Brook and Corang Trig. station. They contain a great number of marine fossils at various levels, and impure alum in certain conglomerate bands. Jensen has indicated a glacial origin for some of the pebbles and erratics.

As on Bulee Ridge, the massive nature of these rocks combines with their widely-spaced jointing to give a formation which is very resistant to erosion. Meridional and transverse joints are developed, but as many of them are irregular, they are widened only gradually by erosion. But master joint planes do exist, and they are responsible for straight lines of precipices where an underlying weak stratum is being weathered away. For this reason, the valleys in the sandstone country are hemmed in by inaccessible cliffs, and outliers of the series generally take the form of mesas.

Older Palaeozoic.—The metamorphic formation of grey slates, quartzites and schists is exposed in the deeper valleys and gorges. It is a continuation of the Ordovician beds first noticed at Tallong, and it grades upward into little-altered sandstones, shales and fissile slates, which occur on the Shoalhaven Plain. These rocks have all been greatly folded; sections exposed in stream beds, in road and in mining cuttings near Welcome Reefs reveal the presence of wedges of softer rock breaking the continuity of the folded strata. Small drag faults are common; there is a great number of quartz veins and reefs exposed on the upland surface, and their erosion from higher and very ancient levels has given the quartz-breccias which occur at Meangora Trig. and on Colombago Creek. The reefs contain a little gold—a fact which has led to a great deal of profitless mining, as the veins and reefs generally cut out within 300 feet of the present surface. Despite the great folding and displacement of these strata, no regional faults or shatter zones have yet been disclosed.

Passing eastward from the Shoalhaven, a series of white and reddish quartzites and sandstones is met with in the vicinity of Nerriga, with the meridional strike common to all of the older rocks in this locality. These are marked as Devonian on the State geological map, but I do not know of any definite evidence to confirm the supposition. Red slates are seen at the junction of Endrick River and Colombago Creek, and these are associated with massive white quartzites which dip eastward at high angles, and can be traced southward to the heights of

Currockbilly and Budawang Trigs. Jensen refers to great anticlines in this latter mass, which he takes to be of upper Devonian age, and which is probably a northward continuation of beds of that age on Clyde Mountain.

The white quartzites appear to be the equivalent of similar beds found to the west of Bungonia and Marulan, and between Lithgow and Goulburn. In this area they determine certain surface features in the upper Endrick and Corang valleys, and they rise southward to form the dominating features of that landscape. Where Permian strata rest on the main ridge of the harder rocks, the passage beds are agglomerates containing huge masses of quartzite. These give place to conglomerates of decreasing coarseness, and to still higher grits and sandstones.

As we have found elsewhere, topography has been determined largely by resistance to weathering and erosion. The higher surface features are of quartzite or horizontal sandstone, whilst the Shoalhaven Plain is developed in less resistant strata. These have weathered to a depth of 200 to 300 feet, and give rounded forms when subjected to erosion. The hard rocks exposed in the gorges hinder downcutting, but they rise to the tableland level (2,000 feet or more) in very few places. Both the Tertiary basalt and drift are weak formations; the basalt has largely succumbed to chemical weathering, whilst the drift is readily eroded by running water.

Topography and Physiography.

1. *Sassafras Range.*—In Australian maps the term "range" denotes a water parting irrespective of its shape or origin. Sassafras Range is an area of tableland separating the Shoalhaven Valley from the coastal slopes, and having an even surface between 2,500 and 2,650 feet above sea-level. It bears a close resemblance to its northern extension, Bulee Ridge, but towards the south a different type of landscape is met at the head of Corang River, where the highest points rise above 2,800 feet and the name "Budawang Range" is first applied.

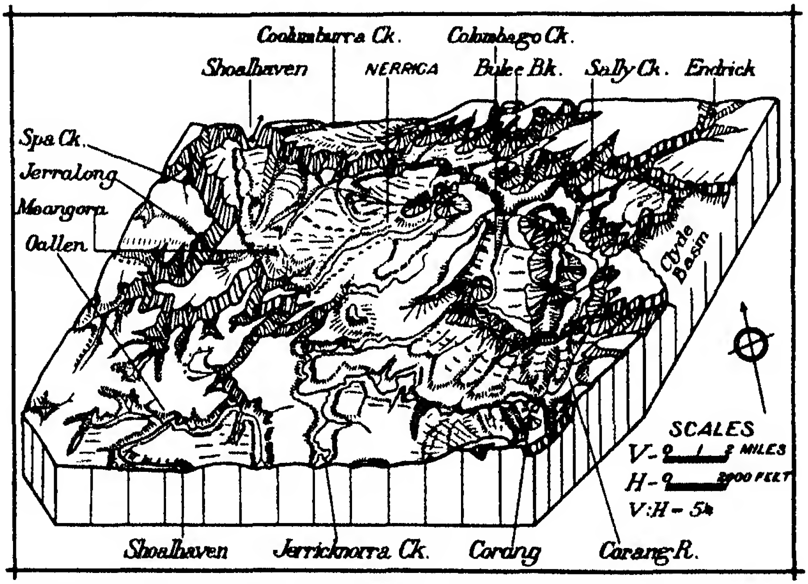
The eastern fall from the horizontal sandstones of Sassafras Range is by a steep monocline to 1,700 feet, whence a gentler slope leads almost to sea-level. The tableland itself has a maximum width of eight miles, and presents a remarkably even skyline when viewed from similar heights at a slight distance. Its surface is broken by rocky terraces on which there are extensive swamps, as the formation is impervious, and cold moist winters favour the accumulation of peaty material. There are areas of moorland on the exposed western section, but the drier places and those with richer soil are forested, and the abundance of sassafras trees on volcanic soil has given the tableland its name.

An area of basalt occurs on the crest and the eastern fall of the plateau; its extent is limited, and its thickness not much in excess of 100 feet. Jensen (1908) associated it with the monocline and faulting into which that feature may have developed, and ascribed a late Tertiary age to it. The great dissection of the slopes combines with irregular bedding in the sandstones to make observation a difficult matter, but the basalt is a local occurrence, and has had no surface connection with the flows of the Endrick Valley, although it antedates the existing eastward fall.

The western side of this higher tableland is an erosion scarp 600 feet high, but broken remnants of a former extension are found on the western side of Endrick River. The scarp is surmounted by precipices up to 200 feet high, formed as the result of long-continued sapping of the massive upper sandstones. Long sections of the cliffs are quite unbroken, but in places where the joints are closer, weathering has produced some fine monuments. Major joints have been widened

in places to give narrow gulches and these, with occasional broken corners, form the only means of access to the tableland. The most notable break is that point used by the Nowra road, where the sandstones are thin and considerably weathered.

Following this scarp from Vines Creek northward, its height and difficulty are found to decrease with the thinning of the horizontal rocks. At Bulee Brook these are found as low as 1,900 feet, but on the Nowra road the base has risen to 2,150 feet, and the higher part of the older surface on which they were deposited continues northward past Cool'umburra Creek until a cross-ridge is reached which runs westward to the junction of the Shoalhaven and Endrick Rivers. Here the sandstones are again found as low as 1,900 feet, but still further north the base rises to Touga Trig. station. The breaking down of this scarp gives a false impression of lowness to the tableland when it is viewed from the hills about Nerriga, and there are few points from which the fine massiveness of the southern portion can be appreciated.



Text-fig. 3.—Block Diagram of the Area. Note the change in land forms as one goes westward from the horizontal sandstones, and the entrenchment of the Shoalhaven and Endrick Rivers.

The streams run parallel to the major joints, of which the meridional have had the most marked effect in determining stream courses. Deep and narrow ravines are found on the eastern slopes, but the Shoalhaven Plain has acted as a base-level of erosion for the western side, thus limiting the depth of those valleys. However, the heads of these in the higher tableland are narrow and difficult of access, and the streams which pass through them from the upland swamps fall to the broad valley of the Endrick by a series of cascades over low precipices.

The western fall was described as a fault-scarp by Jensen—a view which I took to be correct after making a hurried visit in 1927. It is, however, a normal erosion scarp of considerable age, and its relatively unbroken nature is due to the extreme slowness of erosion in the massive tableland block.

Valley of Endrick River. Plates xxviii, xxix; Text-figs. 3 and 4.

The main stream rises at Sassafras and breaks through the western scarp to flow in a wide valley partly filled with basalt. The head of this valley is directly east of Endrick Trig., and its upper slopes are of basalt which has come from a low part of the divide between 2,300 and 2,400 feet, and has poured down a widening valley between perpendicular cliffs, lying 400 to 800 yards apart. There is a further expansion when the main stream is reached, and the Endrick flows for a short distance in a level channel, with basalt on the right and swampy terraces of horizontal sandstone to the left. Small waterfalls carry it below this local plain level, and thereafter its course is in a shallow trench eroded in basalt and in the older rocks. Alteration of the horizontal sandstones at the 2,000-foot level shows that the basalt once extended to the present left bank of the river, and even now a small patch is found on this side immediately above the junction of Sally Creek.

There are great bays in the cliffs to the right where valleys of a triangular plan indent the tableland, but erosion on the left has been far more destructive, and now only isolated relics of the original surface remain. From this side two large affluents are received—Sally and Colombago Creeks—both of which drain extensive swamps.

The valley of Sally Creek is a mile wide, and branches penetrate the higher country. Isolated tablelands or large mesas are found to the east, but there has been greater reduction to the west, where sections of the divide have been considerably lowered. A notable gap is found in the Clyde watershed immediately south of Endrick Trig., where swamps rise from either side into a level col at 2,300 feet. In this locality Sally Creek falls rapidly across quartzite bars, which mark the end of its upper swamps at 2,200 feet. On the downstream side there is more horizontal sandstone, and the gentle, swampy course is resumed until the stream turns slightly eastward to pass into a shallow quartzite gully, which is followed to the Endrick.

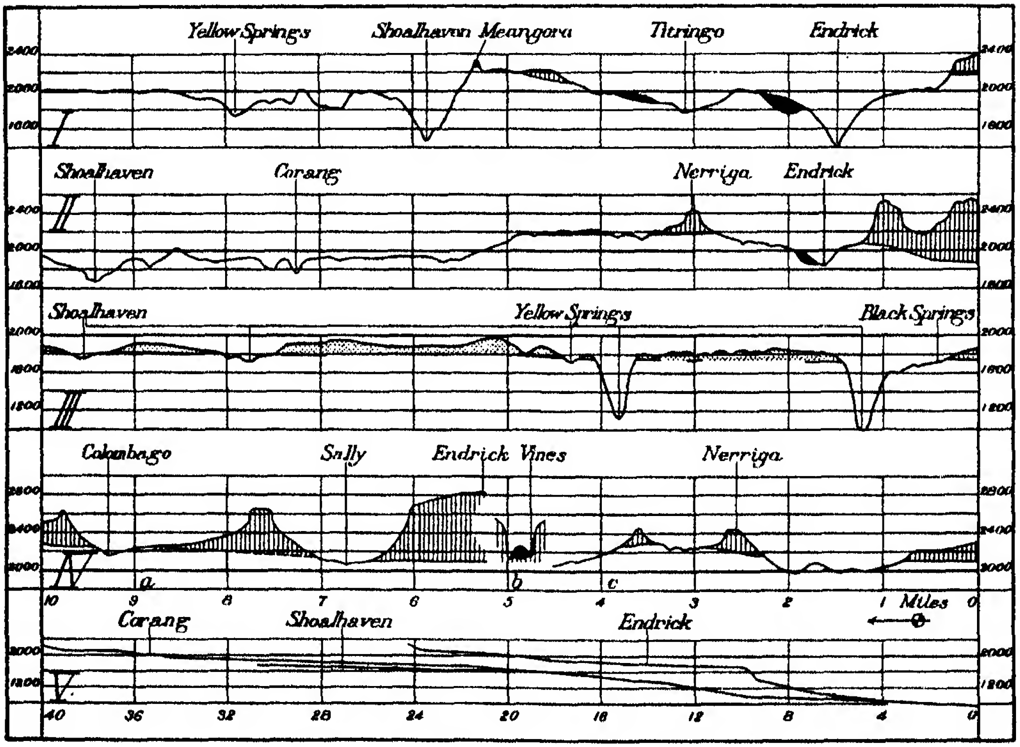
The course of Colombago Creek is similar, but the absence of high-level swamps from its drainage area is reflected in a smaller volume, and the cliffs of its western divide are low and broken. Its valley is wider than that of Sally Creek, and the older sandstones and quartzites which form the lower levels are rough and ridgy.

Continuing along the Endrick, an area of sandy and basalt terraces is entered. A wide tributary valley from the west heads against Nodgengutta swamps, and on the east is the valley of Bulee Brook, hemmed in by cliffs. As the Nowra road is passed the basalt slopes become wider and gentler, but the stream follows a level course through them in a steep-sided trench 150 feet deep, from which it falls into a gorge by a series of cataracts.

The lower part of the valley is marked by the recession of the scarp to the east and by the approach of a level ridge from the west, which divides the Endrick from the Shoalhaven. A dissected and undulating terrace is found between 1,700 and 1,900 feet: drift occurs on the Shoalhaven side between 1,650 and 1,900 feet, and some of its extends to the edge of the Endrick gorge. On the ridge leading to the junction of the streams, sand and grit have been altered to grey quartzite at 1,840 feet, and give an outcrop 40 yards wide. Similar material is found at 1,680 feet, but it may have gravitated from above.

The presence of basalt flows makes this valley particularly interesting, as it preserves the conditions existing before the beginning of the "canyon cycle", and

indicates the amount of erosion which the uplands have since undergone. Part of the basalt comes from "the Vines", where it rises to 2,400 feet on the Clyde watershed. Vines Creek has a lateral branch on either side of the flow (Text-fig. 4), cutting against the original precipices of the sandstone valley. Passing the Endrick at 1,980 feet, the basalt is found as a strip on the northern bank known as the "red ground", and continues beyond Sally and Colombago Creeks, the more northerly extension being chiefly on the left bank. The river swings from side to side of the flow, and has cut through the deepest part of the basalt-filled channel near Bulee Brook. Passing thence to the junction of Titringo Creek, basalt is found again in the river bed immediately below the road crossing, but this may have been a centre of extrusion. Otherwise it forms a series of terraces which



Text-fig. 4. i.—Profile showing the development of the Shoalhaven Plain below the base of the horizontal sandstones (hatched), and its extension into the Endrick valley. The basalts (black) occupy pre-canyon valleys, and the two principal streams have cut gorges in the ancient landscape. Part of the profile west of Meangora Trig. is projected to the line from the north. ii.—Profile south of the gorges. Note the protective influence of the sandstones and the land forms developed. Re-dissection in the Endrick valley has given a trench similar to that which was filled with basalt, and the valleys to the left also post-date the basalt and drift. iii.—Profile of the drifts (stippled) of the Shoalhaven Plain. The section line gives the modern grade of the river compared to its original profile. iv.—*a* and *c*, land forms in the horizontal sandstones; *b*, basalt in the valley of Vines Creek. v.—Profiles of the three principal streams. Vertical exaggeration: i-iv = 5·3; v = 8·8.

have been sharply cut across by the deeper valleys and gorges. Beyond Titringo Creek, from whose valley the basalts have been largely eroded, the course of the flows becomes uncertain as the surface is covered with sand, which has been cemented in parts to a gritty sandstone. Although they continue immediately to the north-west, the basaltic exposures are at a higher level, and it is probable that the main continuation has been eroded by the modern Endrick, and that contributions have been made from the vicinity of "the Bog", where basalt rises to 2,020 feet.

An occurrence of particular interest is found overlooking the gorge at Primrose. Here the base of the flows is at 1,680 feet, and they rest on a thickness of 20 to 30 feet of roughly-stratified coarse drift. The relationship of the drift and the basalt has been revealed by the shafts and tunnels of alluvial miners, who have obtained a little fine gold from the gravels.

There have been a number of flows, giving a maximum thickness of more than 350 feet near Titringo Creek. Layers of solid and vesicular basalt alternate; a little stream drift is found between them, and although it is generally not more than a few inches in thickness, in places to the west of the Nowra road local channels have been filled, to be covered again by the next flow. Most of the gravels have been metamorphosed as a result, although the thicker patches are not greatly changed, and sand is found beneath the flows some distance above the crossing. Weathering and erosion have resulted in the formation of terraces, which are best observed between the road and Titringo Creek. They are bounded by stony banks, and typical levels are found at 1,840, 1,900 and 1,950 feet.

Where Titringo Creek crosses the edge of the basalt at 1,680 feet before plunging into the gorge, it is found to overlie a deposit of horizontal shale and soft white sandstone, from 5 to 10 feet thick. This material rests on folded strata, and has been slightly depressed where the basalt has poured over its thicker portion. Fine white clays are found further up the same creek at 1,900 feet, where they also underlie the basalt, and contain fossil leaves. To sum up:

The valley of Endrick River is found to be eroded in a tableland of the order of 2,500 to 2,600 feet above sea-level. A series of valleys was developed at 2,000 feet; a channel was cut to a depth of 300 to 400 feet in this surface, and was filled with basalt and some drift, which probably extended to the Shoalhaven. Drift is found in places above the basalt, and partly cemented sands occur on the hillsides facing eastward between Colombago Creek and Primrose. Subsequent erosion has given a channel similar to that filled with basalt, but the lower valley has been more deeply dissected by the attack of revived streams.

Upper Valley of the Corang. Plate xxix; Text-figs. 3 and 4.

The head streams of Corang River rise in a desolate tableland, and their upper courses through swamps and gullies traverse unoccupied country. Passing southward and westward from Sassafras Range the sandstone tableland rises above 2,800 feet, although its continuation to the east of Sally Creek is marked by cols of some depth. Coming to the westward turn of the watershed around the head of Corang River, the upper layers of sandstone have been eroded, and a local plain is found at 2,500 feet with a surface broken by a maze of ravines dominated by Corang Trig. station. This peak is a circular cone—a remnant of the higher sandstones—from which the whole expanse of country between the coast and the western divide of the Shoalhaven can be seen. Great precipices here

mark the eastward and southward fall to the Clyde gorges, whilst lower cliffs towards the north fall abruptly to level swamps which feed the Corang.

The heads of this stream flow from the horizontal strata to older rocks in a gentle channel about 2,120 feet until they reach a great bar of light-coloured quartzite, which runs northward under the trig. station and rises to high, square hills across the stream. Here the valley sides close in, and the Corang falls through a precipitous gully in a series of low cataracts, emerging to flow in a shallower trench and a much wider valley, which is also rough and broken. On the right bank, the high ridges either retreat from the stream to give rocky terraces some hundreds of yards in width, or they fall uniformly towards it, with a sharp drop to the river over the last hundred or two hundred feet. On the left, the ridge from Corang Trig. falls steadily, and merges into the general level of the Shoalhaven Plain at 2,100 feet before the Braidwood road is reached.

Approaching this road, the Corang passes to extensive flats somewhat above 1,900 feet as harder sandstones and quartzites are replaced by shales and more friable sandstones. Its further course is over plains or beside low hills until the junction of Corang Creek is neared, where precipitous sandstone bluffs are found on either side. The valley again becomes gentler and shallower as the Nerriga-Oallen road is reached, but the stream soon falls into a steep trench leading to the Shoalhaven.

There are two important tributaries—Corang and Jerricknorra Creeks. The first rises in a level, swampy valley whose sides are crowned with horizontal sandstone; it flows past the Braidwood road and follows a tortuous course across local plains and between gently rounded hills into a shallow gully, which joins that of the main stream. Jerricknorra Creek comes from the tableland near Corang Trig., and passes through broad undulations to the Corang. Its lower valley is level and includes wide flats; the clear and grassy landscape contrasts with the sterility of the higher tablelands.

The Corang and its tributaries are typical streams of the Shoalhaven Plain; their heads are actively eroding in hard rocks, but the lower courses are mature, and lie only a hundred to two hundred feet below a general plain level until the fall into the gorges begins.

Nerriga. Plates xxviii, xxix; Text-figs. 3 and 4.

Nerriga is situated on a depression in the Corang-Endrick sub-divide, which continues as a low ridge to overlook the junction of the Endrick and Shoalhaven Rivers. Towards the south-east are three isolated hills rising 400 feet above the hamlet; they are crowned by cliffs, but the newer sandstones also extend over some of the neighbouring lower and gentler ridges. South of these hills is a great sandy valley, partly occupied by the Nodgongutta swamps and partly by a small creek falling to the Endrick. Their divide is a barely perceptible rise in the level plain, but as one continues southward higher sandstone ridges are reached which separate the valley from those of Colombago and Corang Creeks.

There is a sharp fall from the mesas towards Nerriga and the Endrick River, but the head of Bindi Brook is found in a level valley between them. About Nerriga itself there are two lines of basalt—one in the valley of Titringo Creek, and the other passing Bindi Brook to Nodgengutta Creek. Small eminences near the hamlet are formed of glassy contact quartzite about 2,100 feet, whilst similar material is found on the eastern edge of the basalt at Titringo Creek, and on the sandy plain south of the Nodgengutta-lower Corang stream line. Directly west of

Nerriga a hollow in the sub-divide is partly filled with basalt, and it seems that flows came from this locality to pour over the lower country on either side.

Most of the basalt has been eroded from the valley of Titringo Creek, which is asymmetric, with a steep rise on the eastern side to a ridge composed of soft ancient rocks. Towards the south, Bindi Brook has cut through the basalt line, and continues some distance along a level valley before it falls to the Shoalhaven through a ravine. The valley of Nodgengutta Creek and the lower Corang is simply a shallow trench with a plain at 1,900 feet on the south, and a somewhat higher bank on the north. Small areas of drift and Tertiary contact quartzite rise to 2,040 feet on the sandy southern side, whilst sand and pebble drift also occur between 1,920 and 2,020 feet to the north.

When the dividing ridge turns northward past Meangora Trig., its upper surface is an outlier of the horizontal sandstone, which weathers into low cliffs at the heads of gullies. The westward fall to the Shoalhaven is broken, but gullies from the cliffs on the eastern side widen into valleys as they pass across the sandy and basalt slopes to the gently undulating plain by Titringo Creek.

Still continuing northward, the desolate peninsula of Timberlight is passed on the left, whilst the basalts of the Bog (1,950–2,020 feet) and of Mountainy (1,900–2,110 feet) are found—the first falling eastward, and the second occupying ancient depressions and the heads of old valleys on the divide itself. These appear to be local flows, and a series of level ridges continues north of them at a uniform height of 2,100 feet. At first there is a steep fall directly to the Shoalhaven whilst a terrace at 1,800 feet is found on the Endrick side, but further north these conditions become reversed, and the end of the high ridge falls almost sheer to the Endrick, and overlooks a wide peninsula or terrace between the two streams. This lies between 1,800 and 2,000 feet, and has drift and Tertiary quartzites at the lower level. A screening of pebbles is also found on the high ridge and may represent the weathered remains of Permian conglomerate, as relics of sandstone and grit of that series occur at 2,000 feet at the north-western head of Mountainy Creek.

It will be seen that this ridge rises a little above the level of the Shoalhaven Plain, and distinctly above the basalt-filled and drifted Tertiary valleys. But south of Nerriga Trig. the horizontal sandstones have not only been cut through, but a level valley has been formed and partly filled with sand (in places consolidated by iron oxide), along which water may have flowed in either direction through its whole length about the period of basalt flows, for the basalts at either end of the valley rise above the present indefinite divide which crosses its floor. But even here no appreciable change in stream direction is indicated, although this place and the break at Nerriga show how such a divide can be lowered in places by attack from either side.

The Shoalhaven Plain. Plates xxviii, xxix; Text-figs. 3 and 4.

Passing westward to the vicinity of the Shoalhaven River, a different type of country is entered. A quartzite hill rises to 2,250 feet between the Braidwood road and Corang Creek, but it falls away to an extensive plain whose highest point is rather short of 2,100 feet. In the vicinity of Welcome Reefs and of Oallen Ford this plain surface presents a very even skyline and, although it has been considerably dissected, it remains the most striking feature near the Shoalhaven.

If we take the western section of the contour map, the even ridges are prominent. An examination of the field shows another thing—hard rocks are

absent from a large part of the uplands, although they occur in the gorges and even in some of the shallower valleys. The upland slopes are of argillites and soft sandstones; the dominant colour of the countryside is yellow—the ridges, the slopes and the gullies alike share this feature, which is due to hydrated iron oxide in the weathering strata. The downward limit of weathering is found between 1,700 and 1,800 feet, so the surface of the original plain in the vicinity of valleys is thoroughly rotted to a depth of 200 or 300 feet, and is very susceptible to erosion. Near Welcome Reefs, mining operations on the surface at 1,900 feet show the original stratification to be well preserved, but the decomposing clay rocks have a soapy feeling, and break up readily on exposure to air.

Where sandstones occur the groundwater has been able to circulate more readily, and it has carried iron in solution to the surface. This has been redeposited in joints and cracks, adding greatly to the hardness and resistance of the rock. In other places, surface deposition has given masses of limonite, which form knobs on the hillsides. The high points generally owe their existence to these surface features, and once the hard crust is removed, the unprotected weathering rock is rapidly eroded to give cols in the ridges. Such conditions exist on either side of the river with the exception of those places covered by drift sand and pebbles. The landscape is characterized by rounded forms; the valleys are wide and trough-shaped, and are asymmetric where harder rocks occur closer to the stream on one side, either in the valley or on the tableland surface. The hilltops are rounded, and the lowering of ridges at the heads of gullies gives a confused appearance to the dissected parts. All of these features are well brought out by the contours.

This part of the tableland is of particular interest, for it is here that the river becomes entrenched in the uplands. Near Oallen Ford, the stream is 200 feet below the Shoalhaven Plain; steep bluffs are found in places along its course, and a gentle fall to the east of Oallen contrasts with the sharper and more gullied slope across the river. Immediately below the ford the banks close in, and the river occupies a rocky channel to Welcome Reefs, where Ningee Nimble Creek is received. This stream drains a series of wide, gentle valleys, but its lower course is in a stony bed swinging between precipitous bluffs. Below its junction wide gullies are found on either side of the river, which follows a gently-falling course of considerable roughness, with rising cliffs in places. This section may be viewed from the hills above the Corang junction (Plate xxix); at the confluence of that stream both it and the Shoalhaven are hemmed in by cliffs, which form a gorge 300 feet deep. From here the grade of the river becomes steeper, and although in places the slopes on one side or the other are gentler for short distances, the channel becomes steadily rougher as the river cuts across bars of hard rock. On the outer bends huge bluffs rise sheer from the river to a height of 400 feet, but they do not extend for any great distance. Passing Meangora Trig. the river sweeps around Timberlight, falling tumultuously through narrow crevices in the rock bars. With increasing depth the gorge takes the form of a steep "V" in section, and the widening below Jerralong Creek gives a most impressive character to the scene. There are no considerable streams from the right in this section, and those on the left fall sharply to the river, the waterfalls on Jerralong Creek being very fine. In places the northern side of Timberlight slopes to the river at an angle of 60 degrees.

Much of the river's work has been done in weak rocks, and the presence of highly resistant strata at the lower levels has retarded downcutting, and has

helped give a smooth profile. The Endrick, on the contrary, has cut down through a more uniformly resistant part of the formation—not so hard as the rocks of the Shoalhaven channel, nor so readily eroded as those of the uplands—and the result has been the formation of a uniform "V"-shaped trench (Plate xxix). The upper limit of the most effective attack is found in a series of falls across a huge bar of grey quartzite, whereas the Shoalhaven has a gentler fall over a longer distance, and is lowering the sloping section at a more uniform rate. But even where its grade is gentle the Shoalhaven is a turbulent stream, as its course is broken by bends, rocks and bars. In time of flood the rush of water in its gorge shakes the hills, and most of the rocks borne by the river are reduced to sand and mud long before the eastward bend is reached at Tallong.

Let us now retrace our steps through the uplands, this time passing over the high-level drift.

This begins near Mountainy Creek about 2,000 feet, where it appears to be overlain by basalt, but the first notable deposits are found on Timberlight peninsula, where the aggregate thickness of 270 feet rests on 6 feet of heavy ferruginous conglomerate, which is overlain by laminated clays, pebble and sand beds. These are similar to those recorded immediately to the north at Black Springs and Spa Creeks; the lowest points on their base are at 1,720 feet, and the basal conglomerate occupies channels across parts of the peninsula. The clay beds differ from those observed elsewhere in containing very little plant material, but otherwise there is no great difference between them and their northern extension on the opposite side of the gorge.

Passing to Yellow Springs Creek, part of tho clay is replaced by quartz gravel, but the general nature of the deposits does not change. The base lies at 1,740 feet, and like similar strata at Timberlight, Black Springs and Spa Creek, it has been worked for the gold contained. Extensive tunnels driven into the basal conglomerate reveal its horizontal character, and show its upper surface to be even. A feature of this material is the amount of granite which enters into it. In the natural sorting much of the heavier granite has been left in this upstream section, whilst more of the lighter quartzite has been carried beyond to form the northern parts of the drift at Black Springs. The general diameter of the pebbles is from 3 inches to 12 inches, but exceptionally large masses, including Tertiary contact quartzite, are up to 24 inches on the major axis. Practically all are well-rounded, as the Shoalhaven above Oallen has, and has had, an appreciable grade, and the Corang and Mongarlowe are swift in their upper courses. The virtually horizontal section of the drifted channel between Spa Creek and Oallen may owe its negative grade to a slight local subsidence of the order of (say) 100 feet after the excavation of the channel, and before the commencement of deposition. Relative uplift to the north would give a similar result.

The drift continues southward from Yellow Springs, and only thin deposits are found on the higher ground by the lower end of Corang River. The main bed is cut across by the Shoalhaven at Oallen Ford, and a branch passes into the valley of Ningee Nimble Creek at Welcome Reefs. Above Oallen it is found on either side of the modern stream with a base of 1,790 feet—only 50 feet above the present-day water level—and a broad valley has been partly filled with it. The most southerly extension of the coarse basal conglomerate is immediately below the ford at 1,725 feet, where the pebbles are cemented by quartz crystals and pyrites, and are overlain by clay beds containing abundant plant fossils. This material may fill a local deep of the old channel, for it does not continue upstream for any

distance. Passing to the southern edge of the contour map, the base of the drift has risen above 1,800 feet, and extensive sluicing has disclosed considerable beds of pebbles and sand, crudely stratified in places, and more or less consolidated. Here the fine clays are replaced by gritty brown sands, and there are great numbers of round pebbles with diameters up to 9 inches. These features are in conformity with the rising base of the deposit and with the conditions under which the greater part of it was laid down.

It may be contended that a powerful current was necessary for the transportation of the large pebbles in the basal conglomerate, and that the present grade of the old channel between Oallen and Spa Creek would not allow of this. It must be recognized that there are possible small errors in the various heights which I have given, and that earth movements which elevated the plateau may have produced slight differences from place to place, but my figures showing a variation from the horizontal through a range of 20 feet between the points named cannot be far from the truth, and in any case the validity of the subsequent argument is not affected. The channel was approximately horizontal when deposition began, and erosion was proceeding upstream in the Shoalhaven Plain, with a base level corresponding to the modern height of 1,600 feet. The main stream and its tributaries, on coming from their swifter upper courses to the level channel at Oallen, tended to drop their entire loads in still water which had been ponded up by a blockage in the channel considerably downstream. In time of flood this material was carried northward and distributed in the level channel, for the accumulation upstream and the consequent local fall given to the river in that vicinity would give the current sufficient power to sweep the material along for some distance, in the same way that a breaking dam in a level valley would be carried down by the impounded water. Such a combination of circumstances would be sufficient to give a layer of coarse material in the level channel with a reasonably uniform thickness, such as the conglomerate stratum which we have recorded.

The rising local base level due to further obstruction of the stream to the north would check erosion in the channels being cut in the Shoalhaven Plain and would, in effect, restore those conditions of general maturity which had existed before the commencement of this dissection. The supply of large pebbles and masses of rock would gradually cease, and the largest pebbles would be those brought from the vicinity of the divides, from a landscape which had already been subjected to erosion over the period of time involved in the formation of the 2,000-foot level (i.e., the Shoalhaven Plain). These would be dropped when the current first became less swift, whilst the greater part of the finer material would be swept further on, and then deposited. This would account for the gravel and clay beds, and intermediate pebble horizons, such as that at 1,900 feet in the Nerrimunga Creek area, could be ascribed to widespread scattering of the pebbles under conditions of very shallow water after the existing lakes had almost been filled with drift.

The origin of the material involved may be briefly noted, although more ample information will be given in a subsequent paper. The granite pebbles of the lower conglomerate were derived from the river channel above Oallen, and the quartz gravel from mature granite slopes in the uplands about Braidwood. The clay came from a similar source, and from the argillites of the Shoalhaven Plain, whilst the quartzite pebbles were derived from Upper Marine conglomerates and

from quartzite beds towards the divides. A wide area may have contributed the sand which forms the upper part of the drift.

Andrews (1910) has noted similar beds in the valley of the Lachlan about Parkes and Forbes. Their nature and history bear a close resemblance to those of the Shoalhaven sediments, and suggest that similar conditions prevailed in the two places. In the case of the Lachlan valley, Andrews ascribed sedimentation to subsidence, but a similar view would not account for all the peculiarities of the Shoalhaven, as we shall see presently. A layer of pebbles corresponding to those at our 1,900-foot level was explained as being due to increased erosion following a revival of streams, which was brought about by uplift towards the source of the river. These pebbles were, in their turn, overlain by clays, and such a drastic change in the nature of the drift cannot be reconciled to the idea of notable uplift in the drainage area involved, even if we allow for a considerable lapse of time between the two. The clays correspond to the finer drift and sand overlying the 1,900-foot pebble beds.

A more likely explanation would involve a change in the incidence of rainfall. At the present time, for example, much of the rain is given by comparatively few storms, and the depth of the Shoalhaven at Oallen varies from zero to fifty feet. Under such conditions, streams which are level and normally of slight volume are capable of transporting large rocks and pebbles in times of flood, thus giving their courses an anomalous appearance. The advent of this type of rainfall regime would increase both the amount of erosion and the size of the material transported, whilst a return to less stormy conditions would have the opposite effect, and would also allow weathering to disintegrate rocks much more thoroughly before erosion takes place. The upper pebble horizons can be ascribed to periods of greater storminess, but not necessarily to periods of heavier annual rainfall.

In conclusion, we may define the Shoalhaven Plain in this area as being a deeply weathered surface about 2,000 feet which had been trenched to a depth of 300 feet about the time of basalt flows. The main channel was subsequently filled with drift, which was also spread over parts of the neighbouring plain, and has since been cut across and considerably eroded. As with Nerrimunga Creek, the Shoalhaven falls gradually past 1,700 feet, but the fall below 1,600 feet is steep, although it has been partly regulated by the hard rocks encountered. Further consideration will be given to the alluvial deposits under the heading—"Tertiary Valleys".

Land Forms.

Many of the essential features of the area are similar to those of the more northerly parts of the Shoalhaven Valley, but local variations and unique developments call for description, which might deal specifically with the higher levels and with the Tertiary valleys.

The Higher Levels.—The first suggestion of a peneplain level is found between 2,400 and 2,500 feet, comprising parts of the country at the head of Corang River and the level, swampy valleys of the high tablelands. There are higher levels about 2,800 feet, but they are of too fragmentary a nature to yield inferences of any great value. In some places, such as the vicinity of Endrick Trig., relics of broad valleys exist 300 feet below the highest points of the landscape, and are the results of normal erosion and not of exaggerated terrace weathering of the type noted on Bulee Ridge. There is a possible correlation between this level and similar features in the Tallong and Nerrimunga Creek areas, and in the valley of

Mulwaree Creek to the west. The description of these isolated features as relics of an ancient peneplain is at least justified in the fact that the present Shoalhaven valley has been formed by the removal of rocks which rose to the height of Sassafras Range and Bulee Ridge. Valleys now occurring about this level were formed when the base-level of erosion was considerably higher than the position which it occupied, relatively speaking, during the erosion which formed the Shoalhaven Plain.

Of the nature of this second level there is no doubt. It extends far into the block of horizontal sandstones, and while it exists on them in places, elsewhere it is cut to 300 feet below their base (Text-fig. 4). The great extent of the 2,000-foot level to the west of the horizontal rocks further emphasizes its independence of them, and while local terraces and precipices are explained in terms of sapping and the so-called benching action, the regional features are essentially independent of such factors, and occur impartially in horizontal and highly folded strata.

This level is pre-basaltic in age, and its relative narrowness in the Endrick valley is due to the resistant nature of the rocks in which much of the cutting has been done. On the slopes east of Meangora and Nerriga Trig. stations, mechanical erosion has not been very active since the volcanic period, for the slopes and parts of the basalt flows are still covered with sand which has been partly consolidated into a gritty white or red sandstone. The width of the Endrick valley in these places has changed very little in the time involved.

The process of destruction in the massive sandstones is of interest. Attack is along joints, and may be considerable even away from permanent streams. Take the ridges between valleys as examples; tributary gullies extend into these ridges along the most notable lines of weakness, and fissures are formed along the same lines which, in time, cut right through the ridges. These are well developed in the tableland at the head of Corang River (Plate xxix) and in the cliffs near Bulee Brook. In the former case the fissures are from a few inches to several feet in width, and their further development has given narrow ravines which cut right through the Corang-Clyde divide. In the course of time, after a fissure has extended downward to a weaker stratum, widening commences and the sides of the fissure, being attacked from beneath, recede to leave a gap in the ridge, possibly at quite a low level. This process is accelerated because angles in the cliffs are involved, and these constitute natural weaknesses.

A typical example occurs south of Bulee Brook, where the original end of the ridge is a mesa separated from the tableland by a level col, which slopes away gently on either side to a wide valley (Plate xxix and Text-fig. 4). The hills and passes west of the Endrick between Nerriga and the head of Corang River have a similar origin, and in places the action has been carried below the base of the horizontal rocks to approach 2,000 feet.

This gives an insight into the country around Tallong, where there has been considerable erosion under similar conditions, but through a smaller vertical range. There, wide valleys also head in breached divides, and the level forming the Shoalhaven Plain extends to the heads of the streams. Again the horizontal sandstones in their harder portions rise above the more easily eroded members of the older rocks.

Tertiary Valleys.—We have noted the pre-basaltic valleys eroded to a depth of 300 feet in the Shoalhaven Plain. Those on the Shoalhaven side were filled with drift, but that of the Endrick with basalt. Further erosion has been accomplished in stages; the first resulted in the formation of trenches or channels very similar

to those which had been filled, and the second involved the cutting of deep gorges. The first were carved under conditions similar to those existing before the basalt flows and sedimentation, or such a coincidence as that noted would hardly be possible. We may ask—how much erosion has been accomplished in the Endrick valley since the outpouring of the basalts? The answer has already been given for that section by Nerriga and Meangora Trig. stations, and there is no reason for supposing a much greater degree of widening further upstream. The valleys and gorges below the level of the basalt are of recent origin, as are the gullies in the floors of the valleys of Colombago and Sally Creeks, since these occur below the basalt and drift. But the valley of Vines Creek, which breached the Clyde divide, is entirely pre-basaltic (Text-fig. 4), and there seems to be no reason for coming to a different conclusion when considering the other mature and swampy valleys of the Endrick heads. In the main valley the cliff scarps approach the basalt in many places; the precipices tend to rounded forms and monuments on their crests and in their broken parts, giving an appearance of considerable age, and indicating that a condition of stability had been reached before the trenching of the 2,000-foot level. *Similar conditions are shown in Plate xxix.*

But although there has been no essential alteration in the dimensions of this valley, or rather, in that part unaffected by the "canyon cycle", it must not be thought that the process of erosion in the uplands has come to a standstill. The streams coming from the cliff bases carry pebbles with them, and after rain new sandbanks and strips of shingle may be observed along their courses, although erosion is reduced to a minimum by the presence of trees, heath and swamp plants which have not been interfered with by man. In addition, drift overlies the basalt in parts, especially near the mouth of Colombago Creek and thence towards Sally Creek, where large pebbles are observed which were probably derived from the Upper Marine beds.

Similar conditions appear to have existed during the period of basalt flows; there are pebbles between the various lava sheets, an old stream channel has been recognized near the Nowra road, and the basalt at Primrose is underlain by 20 to 30 feet of coarse drift. But the absence of any thickness of drift between the basalt sheets is more remarkable than these occurrences when we consider the deep drift in the neighbouring Shoalhaven valley, and the erosive competence of the upland streams of the Endrick. For if similar conditions had prevailed in the two co-existent valleys while the Shoalhaven deposits were accumulating, the basalt sheets of the Endrick valley would alternate with thick layers of drift.

There are two possible explanations of this: either the filling of the Endrick valley with basalt prevented the accumulation of sediments in it, or those flows and their equivalents further to the north filled the trench in which the Shoalhaven was flowing, and caused the accumulation upstream.

Let us assume the necessary conditions for the first case and disallow the second for the time being. We can now explain deposition by a relative uplift northward, or by a general subsidence of the land surface to give a negative base-level of erosion. (This latter condition would be satisfied if the channels were carried below sea-level as it then existed.) It has already been shown that differential uplift northward was not considerable; the meridional profiles of the Shoalhaven Plain between Oallen and Tallong, the profile of Bulee Ridge and the existing grade of the drifted channel combine to attest this, and even if we allow a relative uplift of the order of 100 feet towards the north, it explains the flattening of the old channel but not the sedimentation. Differential uplift imme-

diately to the north of the lower Shoalhaven during or since the outpouring of the late Tertiary basalts is discounted by the topography of that area, and by the uniformity of the base of the basalts between Warrima (near Tallong) and Robertson. The study of Tallong disclosed no differential movements in its vicinity, and certainly no late- or post-Tertiary uplift to the east (see also Craft, 1928).

The idea of general subsidence is complicated, as it involves uplift to allow the trenching of the Shoalhaven Plain, thus lowering the effective base-level by 400 feet at the mouth of the Endrick; then subsidence of the same order which was almost immediately followed by the filling of the Endrick trench with basalt; then by uplift, again of the same order, following the deposition of the drifts and allowing a new channelling of the Shoalhaven Plain and of the Endrick valley, and finally by the uplift which made the erosion of deep gorges possible. The coincidences of such an explanation do not recommend it, and movements of large areas are postulated in order to explain localized features. In addition, the nature of the coastal slope must be considered, for it shows the effect of much erosion accomplished before the cutting of the deep gorges, as we have seen at Tallong and on the slope falling from Sassafras Range to Nowra.

Considering the second of our alternatives—that of basalt filling the stream courses and causing sedimentation upstream—an explanation that would only satisfy conditions south of the Endrick junction is insufficient, for the alluvial deposits also occur towards Tallong. It is possible that basalt issued from the Endrick valley, as contact quartzite is found at 1,840 feet overlooking the junction of the Endrick and Shoalhaven Rivers, but this feature does not appear in the drift across the gorge immediately to the north.

About Tallong, however, there are basalt flows and centres of extrusion on either side of the river. Parts of them are sharply cut off by modern precipices, and there are extensive remains of contact quartzites about the 2,000-foot level in that district to mark their former greater extent in the vicinity of the modern canyons (Papers i and iii of the series). The Caoura flow rises to 2,080 feet and begins on the Shoalhaven cliffs near Badgery's Lookout, and there is every probability of its having extended into the valley of the main stream and having risen to that same level.

Tertiary quartzites in the drift show it to post-date the commencement of volcanic activity, and in such places as the vicinity of Bungonia Lookdown, Inverary, and above the junction of the Corang and Shoalhaven we find basalt or its contact quartzite lying on the higher levels of the drift. Intermediate stages have been noted in both the Nerrimunga Creek and Nerriga areas in association with the drift, further demonstrating the intimate connection of the two phenomena. Lava flows commenced before the beginning of deposition, and lasted until after the 2,000-foot level had been attained. Their extent and thickness have been shown, but we may again quote the Caoura and Endrick flows; the former lies between 1,850 and 2,080 feet, whilst the latter has an extreme range between 1,680 feet at Primrose and 2,160 feet by Titringo Creek at Nerriga. Even taking the upper level of the flows as the 2,060 feet recorded close to the Nowra road above Endrick River, it is clear that sufficient basalt has existed in the Shoalhaven Valley to block the streams entrenching in the 2,000-foot level, to cause the accumulation of drift and its ultimate spreading out on that plain surface. Moreover, the idea of a gradual or intermittent rising of the barrier to account for the diversity of the various layers of drift is one which finds adequate recognition in

this explanation, and the relative absence of drift between the basalt sheets of the Endrick valley is not difficult to understand, even if the flows occurred at the same time as those near Tallong which were the primary cause of deposition. It is possible that the two synchronized, and in any case the notable Endrick flows had only to sustain a level in the comparatively narrow valleys they were filling in excess of the effective level of deposition. We thus find a satisfactory explanation of all the facts involved without having recourse to the postulation of widespread and arbitrary earth movements.

To summarize this briefly: Uplift resulted in the erosion of valleys from 300 to 400 feet deep in the levels of the Shoalhaven Plain. Basalt flows filled the trench of the Endrick, and similar flows near Tallong interrupted the cycle of erosion and caused the filling of the Shoalhaven trench with sediments, which spread over the neighbouring plain. After the cessation of volcanic activity the barrier was cut through and the drifted plain was channelled to give forms similar to those of pre-basaltic times. The Endrick, confined in a restricted valley, did not depart far from its original course; but the Shoalhaven, wandering over the plain, assumed and maintained a highly irregular pattern which was probably determined, in part, by the incidence of its tributaries, and which differs considerably from the original linear outline.

Physiographic History.

Relics of the Kanimbla folding which affected all the rocks up to the upper Devonian occur in the form of quartzite ridges in the south-east of the area. The Upper Marine Series, of Permian age, were deposited in the east on a subsiding peneplain of some irregularity, and the modern Shoalhaven occurs immediately to the west of their periphery. It is unlikely that the Upper Coal Measures had any great thickness in this area, and probably the Triassic rocks did not extend into it at all. In fact, a stream following the Shoalhaven line along the crest of the greatest of the ancient folds may have contributed to their formation. Evidences of an old peneplain of indeterminate age are found at a modern height of 2,500 feet, whilst older levels are found still higher. In the late Tertiary period the Shoalhaven Plain, already a very ancient feature, had been carved out of the folded and intrusive strata (the latter occurring further south), and the dissection of the horizontal rocks had been carried to maturity. This plain was probably not more than a couple of hundred feet above the existing sea-level, whilst the sandstone tableland rose 800 feet higher. Effective uplift of the order of 400 feet led to the partial dissection of this surface, but the channels were blocked by basalt flows and filled with basalt and sediment. A period of quiescence then allowed the re-formation of these features, and normal uplifting was resumed to raise the land to its present height, and allow the formation of the modern canyons. It has previously been concluded that the most recent uplifts were rapid and involved a rise of the order of 1,000 feet, but this may be rather understated. In any case, the maximum limit is of the order of 1,400 feet.

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EXPLANATION OF PLATES XXVIII AND XXIX.

Plate xxviii.

Topographic Map of Nerriga District, based on parish maps of the Lands Department. Detail is by corrected compass traverses, and heights by aneroid with reference to Trig. stations.

Plate xxix.

1.—View southward from Endrick Trig. The valley of Sally Creek is in the middle distance, with Budawang Range on the left. Currockbilly Trig. is the high point in the far distance, and the square hill to the right of it is also of quartzite, which continues northward across the left of the light patch in the valley. Colombago Creek is between the ridges in the right background.

2.—View eastward from Corang Trig., showing the levels about 2,800 feet, and the terrace at 2,500 feet cut across by ravines. Pigeon House (2,358 ft.) lies to the right beyond the Clyde gorge.

3.—Pre-canyon valley of the Shoalhaven, looking upstream from near the junction of Corang River. The level of the Shoalhaven Plain is shown, and the drift-filled valley lies behind the hill to the right.

4.—The valley of Endrick River. The sandstone tableland (2,400-2,500 ft.) is in the background; lower levels in the middle distance are an extension of the Shoalhaven Plain, with cleared basalt slopes as a line to the right of the canyon. The ridge at 2,100 feet and the junction terraces are on the right, whilst the Shoalhaven flows across the foreground.

A CLASSIFICATION OF THE GALL-MAKING COCCIDS OF THE GENUS *APIOMORPHA*.

By WALTER W. FROGGATT.

(Thirty Text-figures.)

[Read 25th November, 1931.]

The Genus *Apiomorpha* was established by C. H. Rübsaamen in 1894 (Uber Australische Zoocecidien und deren Erzeuger, *Berlin. ent. Zeitschr.*, xxxix, pp. 17-42). He described and figured five species of the genus with other Australian gall-making insects. This genus now contains all the species previously included in the *Brachyscelis* described by H. L. Schrader, who first called attention to these wonderful gall makers (*Trans. Ent. Soc. N.S.W.*, 1862). He described five species which he collected in the neighbourhood of Sydney. My first contribution to the study of these remarkable creatures was in 1892 (Notes on the Family Brachyscelidae, with some account of their parasites, and descriptions of new species, These PROCEEDINGS, 1892, 353). In the following year, J. G. O. Tepper published a paper (*Trans. Roy. Soc. S. Aust.*) on the coccid galls in the collections of the Adelaide Museum in which he described some new species.

Between 1893 and 1898 I contributed four more papers on these insects to These PROCEEDINGS. In 1896, C. Fuller described some new species in the *Agricultural Gazette of N. S. Wales*. In the following year he described some new species in the *Journal of the Western Australian Bureau of Agriculture*. Later in the same year he amplified these descriptions (*Trans. Ent. Soc. London*) and described the gall of another species. No further species were added to the genus until 1921 when I described three (Descriptive Catalogue of the Coccidae of Australia, Part ii, *Dept. Agric. N.S.W.*, Science Bull. 18).

During the last few years, through the kindness of the Commissioners of Forestry for the different Australian States, their field officers and other country correspondents, I have been able to make a very extensive and interesting collection of gall-making coccids from all parts of Australia. During the last two years I have described five more new species.

In this contribution to the study of the Genus *Apiomorpha* I have mounted the skins of the adult female coccid and defined the species upon the arrangement of the hairs and spines on the dorsal surface of the derm, and the structure and form of the remarkable anal appendages peculiar to the members of this genus.

The female coccids have been boiled in ten per cent. caustic potash, the contents of the body washed out, treated with spirits of wine, chloroform, turpentine, and mounted on glass slips. The specimens do not require to be stained, and when treated in this manner give a clear outline of all the external structure.

Through the courtesy of the Council for Scientific and Industrial Research, who made me a grant for the purpose, I am enabled to illustrate this paper with outline drawings of thirty species made by Miss Ethel King.

These coccid galls are not produced in the same manner as the galls caused through the damage to the plant tissue by other insects. The galls developed from direct injury to the bark by the ovipositor of the wasp, fly, or other phytophagous insect, results from the intrusion of the egg and the subsequent infestation during the development of the larva, in the aborted tissue. In these gall-making coccids it is the free moving microscopic larvae which, burying their rostrum in the bark or leaf, cause the surrounding tissue to grow up and surround them. These larvae, born in the shelter of the mother gall chamber, cluster together in the base of the gall (like a mass of yellow dust) for some time before they crawl upward, and emerge through the small opening at the apex of the gall. They scatter all over the branches and foliage. Under a high power magnification one can see no outward difference in these hundreds of larvae, yet some produce male galls, and others produce female galls, each species with the same specific characters in the gall. If the male galls were always produced upon the foliage and the female galls on the branches one could understand the disparity of the size of these sex galls. This is not, however, the case because we often find large female galls formed on flower buds and, in other species, on the surface of the leaves. The male galls, also, though usually upon the leaves, are often found upon the branchlets side by side with the female galls, and in three species are formed in masses on the side of the female gall. Among the most remarkable forms are the compound galls, comprising three species, of which *Apiomorpha pharetrata* is the type. In this and the allied species, the oval female gall grows out on the surface of the leaf and when well developed, a fold of tissue grows out on one side, becoming many times larger than the supporting female gall. This consists of a mass of coalescing pits or tubes, each containing a larval male coccid, several hundred winged males often emerging from the one folded mass. As all the larvae emerge from the old parent gall at the same time, how do these males repress the gall-producing activities until the female gall is in a condition to support them? In the case of *Apiomorpha ovicola* and *A. helmsi*, large galls of solid woody tissue, how do they produce such a mass of matter through the tiny flower bud or seed capsule of a redgum tree, from which they are often developed? The development of these large galls is rapid; most of them complete their life cycle in the year. During their earlier stages of growth the apical orifice is closed, either by a folding over of the edges or a little plug, which contracts and falls out as the gall matures. Two species only have a distinct oval-elongate apical orifice: in one, *Apiomorpha pileata*, the young female galls are protected by a pointed cap of woody tissue which, with the growth of the gall, often expands into a long pointed tail several inches in length, drying up from the rounded base, and falling off like a paper envelope. The second species of this group, the largest insect gall in the world, *Apiomorpha duplex*, forms a large solid woody gall more than three inches in length, expanding into long curved tails or horns six inches or more in length. This has an even larger opening at the apex, but no protective covering.

In another, *Apiomorpha hilli*, there are two divisions; the gall chamber in the lower half with a closed summit containing the apical opening, with a solid rim round it; above the cavity is a conical lid, or elongated cap, which cracks off as the gall matures, but previously is the apical portion of the gall.

In most species the substance of the gall is hard and solid, with the inner surface of the coccid chamber smooth. In others, the gall consists of a double layer of woody tissue, as if the bark composed the outer layer and the sapwood the inner hard and woody portion. In *Apiomorpha variabilis* the gall is composed

of solid woody tissue surrounding a small coccid chamber, but there is a bell-shaped cap of softer tissue on the summit, with a rugged opening through it, above the apex of the solid gall. *Apiomorpha fletcheri* is a gregarious species; its infestation causes large irregular swellings on the branches. There are usually three or four coccids hidden in this galled wood, situated under a depression, covered by a scale of dried bark, the apical opening just level with the surface of the live bark. Remove the bark and soft tissue and you find a detachable funnel of hard wood resting on the rim of the coccid chamber, below which is simply an oval pit in the solid wood.

In *Apiomorpha macqueeni* the gall is a solid fig-shaped mass of wood, in the centre of which is a thin slender envelope of woody material readily detached from the woody gall surrounding it, in which the coccid is hidden.

The change from the larva to the first instar of the female coccid takes place very soon after the initial swelling out of the plant tissue, and before the gall is a quarter grown, the enclosed coccid at this stage exhibiting all the external appendages of the adult in a rudimentary form. The virgin female has a thin derm covered with white mealy secretion, and stands on her head with the tips of the anal appendages level with the top of the apical opening on the summit of the gall. She can move backwards and forwards in the gall chamber; when removed from the gall, and laid upon a glass slip, she has a habit of turning the abdominal segments upward and twitching her body. At this stage of development the contents of the body consist chiefly of clear watery fluid.

The full grown female coccid is tinted yellow or brown, the derm tough, and the external appendage chitinous with bands of yellow, reddish-brown, or black chitin, and the anal appendages hard and horny. They vary somewhat in form, but the typical ones are turbinate and are coated with floury secretion which also covers the walls of the gall chamber and the edges of the apical orifice in the gall. Both ventral and dorsal surfaces are clothed with scattered fine spiny hairs, with finer longer hairs fringing the anal segments in some species. Besides the hairs on the dorsal surface there are scattered bands, or regular transverse rows of lance-shaped, conical, or thorn-shaped spines, on the abdominal segments; in exceptional cases these extend on to the thoracic and cephalic region.

The cephalic and first and second thoracic segments coalesce to form an oval body; the third thoracic segment, round on the sides and across the basal margin, forms a distinct band which might be likened to the waist, and the tapering rounded anal segments to the tail. The cephalic forms a rounded fold with the first thoracic segment, in the centre of which are the aborted antennae, below which are the small fore legs, with the mouth in the centre between them. The two anterior spiracles are on either side above. The second thoracic segment is very broad, with a v-shaped cleft in the centre below the mouth forming a pit with a wrinkled area on either side bearing the second pair of legs, and a transverse fold below, deeply divided on the apical margin by the segmental division between it and the third thoracic segment. This bears the larger hind legs, and the posterior spiracles just above the base of the legs. There are seven abdominal segments, the first six well defined, but the seventh much reduced in size and coalescing with the base of the anal appendages, a pair of horny pointed lobes, which occupy the tip of the anal segment in some species; in others they occupy the dorsal half and the fringed anal ring is behind them on the ventral side; in others the anal ring is situated at the base of the anal appendages. The gravid

female is a sac of larvae which, as they are born, leave the moribund mother a wrinkled skin in the bottom of the gall chamber.

As previously noted, in a number of species the male galls outnumber the female galls by thousands; in one species in particular, the four-horned gall-maker, *Apiomorpha munita*, great masses of the tiny tubular galls, resembling a bunch of coral, may be on a branch with not more than fifty female galls. The delicate pink two-winged male has been described in my first paper (These PROCEEDINGS, vii, 1892, 356). They develop in the tubular galls with two long white filaments produced on the sides of the slender body, extending beyond the end of the gall chamber. The larvae, after emergence from the body of the mother, congregate at the bottom of the gall chamber and remain in a semi-dormant state for some time before they crawl upwards and escape through the apical orifice. They are to be found in the galls in September and October. They are pale yellow, flattened little creatures, oval in form, with a cleft in the cephalic margin, between the base of the seven annular jointed antennae. The anal segment is produced into two rounded lobes. The eyes are black, the legs long and slender, with the tarsal claws sharp and usually with a pair of digits. The whole body is fringed right round with fine sharp spines.

In the present paper I have briefly described the male and female galls, and given the range of the different species, and the specific name of the host eucalyptus. I am giving a group classification of all the species of the genus, based on the form and disposition of the hairs and spines on the dorsal surface, and the structure of the anal appendages. There are two species which I cannot place: *Apiomorpha Karschi*, described by Rübsaamen, probably a variety or abnormal specimen of *A. fletcheri* and *Apiomorpha cucurbita* described from the female galls only by Fuller.

Classification of species of *Apiomorpha* by the structure of the female galls and the arrangement of the hairs and spines on the dorsal surface, together with the form of the anal appendages.

Group A.—Galls solid, sessile, formed on the branchlets or stem; apical orifice an elongate-oval slit. Coccid with the anal appendages widely separated at the base, long, slender, broadest at base, with a tuft of long hairs at the tips .. *duplex; pileata.*

Group B.—Gall variable in form, rugose at apex, with the apical orifice small, circular. Sessile on twigs or branchlets. Coccid with the anal segment very long and slender, anal appendages not coalesced with anal segment, long, slender, flattened, turning outward from the base, bifid at the tips .... *urnalis; macqueeni; umbellata; sloanei.*

Group C.—Galls formed on the leaves, slender or elongate-oval. The apical orifice small, circular. Coccid with anal segment without spines, conical. Anal appendages not coalescing with the anal segment, slender, sabre-shaped, with the bases occupying only the dorsal half of the anal segment, tips slightly bifid .... *pharetrata; thorntoni; rosaeformis; spinifer; fusiformis.*

Group D.—Galls oval, smooth or fluted, sessile, apical orifice small, circular. Normally produced upon the branchlets, but often growing out of the flower buds. Coccid with the dorsal surface covered with scattered thorn-shaped spines. Anal segment longer than broad, anal appendages coalescing with anal segment, which is broad at the base, round and rugose on the sides and with the anal appendages forms a lance-shaped tip, which is slightly bifid .... *ovicola; helmsi; withersi; floralis.*

Group E.—Galls consisting of oval pits in masses of galled wood upon the branches, with a detachable funnel-shaped cap perforated at the apex, which fits over the chamber below. Dorsal surface without any large spines, very chitinous, anal segment and anal appendages coalesced, broad at base, tapering to the tips .... *fletcheri.*

Group F.—Galls oval, sessile upon the branches, covered with fine curled filaments. Coccid with abdominal segments chitinous, fringed with fine spines, short anal segment, rounded at the base, coalesced with the short anal appendages which are broad at the base, with the tips peg-shaped and curving outward, and fringed with fine hairs, bifid at the tips .... *dipsaciformis; excupula.*

Group G.—Galls variable, usually sessile and broad at the base, sometimes slender and stalked. Apical orifice small, circular. Coccid with few or no large spines on the thoracic and first two abdominal segments. Anal segment longer than broad, truncated base; anal appendages broad at base, rugose, cylindrical, tapering to the tips which open out from the base into pointed tips; coalescing with anal segment .... *pedunculata; longmani; frenchi; conica; attenuata*

Group H.—Galls sessile, rounded, slightly flattened or depressed on the apex, with small circular apical orifice. Growing on the branchlets. Coccid very lightly clothed with large spines. Anal segment and anal appendage forming an elongate triangular point, the sides serrate, with blunt or bifid tips .... *globosa; maliformis; strombylosa; variabilis; baeuerleni.*

Group I.—Galls rather small, sessile, rounded at the base, with or without terminal appendages. Apical orifice small, circular. Coccid with the abdominal segments small, chitinous, fringed with fine hairs. Spines on dorsal surface scattered, usually some on the thoracic segments. Anal segment and anal appendages coalesced, broad and rounded at the base, curving out in the centre, with the tips small and bifid .... *munita; hilli; sessilis; minor; dumosa; rugosa; annulata.*

Group A.

APIOMORPHA DUPLEX Schrader. Text-figs. 30, 30*a*.

This large gall is found from Sydney to Newcastle and the Blue Mountains upon *Eucalyptus saligna*, *E. piperita*, *E. haemastoma*, *E. Camfieldi*, and *E. eugenioides*. Other records are given in These PROCEEDINGS, lv, 1930, 471.

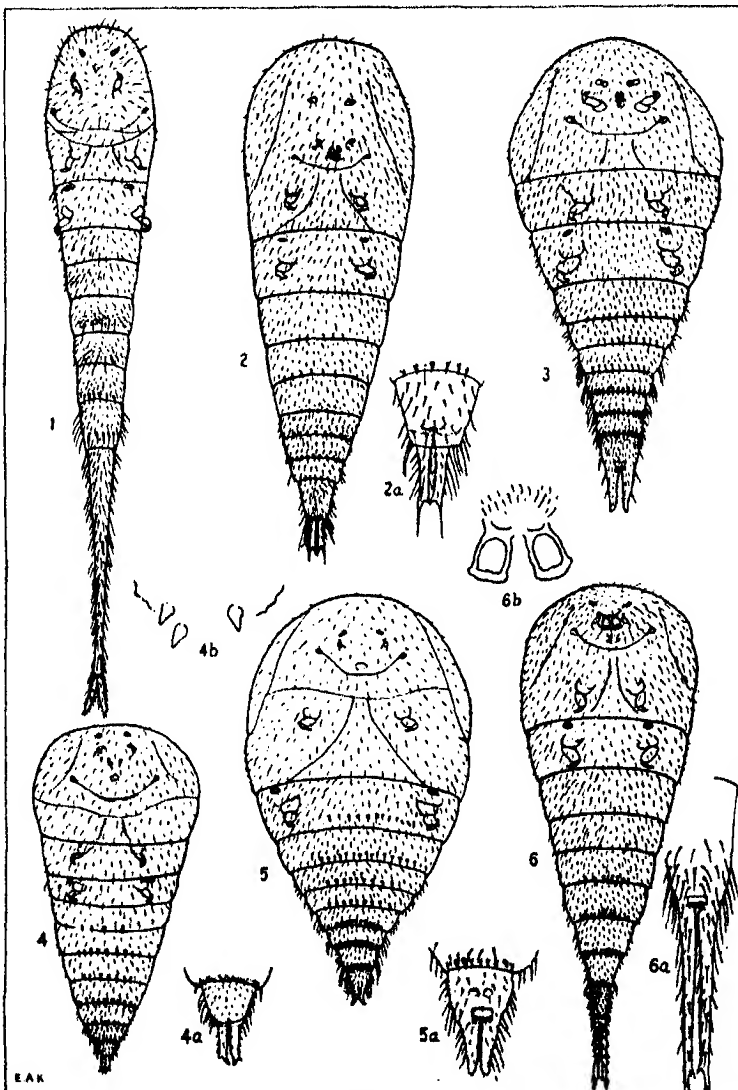
The female gall is sessile, growing out from the side of the branch, swelling out into a green four-sided, elongate, ridged mass of solid woody matter, 3 inches in length from the base to the apical orifice. The orifice forms a narrow slit between the two flattened curled leaf-like horns, often up to 7 or 8 inches in length, which project on either side of the solid basal portion. As the galls mature they turn brown and are much more noticeable among the surrounding green foliage. This remarkable gall has been figured several times. Schrader gave a drawing of it when he described the type. The late Mr. Grose (*Agric. Gaz. N.S.W.*, 1898) gave a life-size drawing which was reproduced in my "Australian Insects," 1907. Tillyard (*Insects of Australia and New Zealand*, 1926, Pl. 14) figures a very slender form.

♀. Coccid 1¼ inches in length, broad in proportion, thickly covered with floury secretion which is also thickly coated over the walls of the gall chamber. Derm lightly clothed with some very small slender spines and annular pores on the cephalic and thoracic segments. Abdominal segments thickly covered with very long spiny hairs and more annular pores; the hairs form regular bands across the segments interspersed with lance-shaped spines; 1st and 2nd segments with small lance-shaped spines among the hairs, 3rd with larger lance-shaped spines forming an irregular band; 4th to 6th with similar spines arranged in a regular row across the lower portion; in the 4th and 5th segments the spines are grouped in two or four. Anal segment spineless, but lightly clothed with long spiny hairs; round on the sides, with the anal ring fringed with fine hairs in the centre, at the base of the anal appendages, which, coalescing with the anal segment, are broadest at the base, widely separated from each other; long and slender to the pointed tips, which are fringed and tufted with long hairs.

APIOMORPHA PILEATA Schrader. Text-figs. 11, 11*a*.

This distinctive gall is found in the vicinity of Sydney, chiefly upon the branchlets of stunted specimens of *Eucalyptus Sieberiana*. I have specimens upon *E. umbra*, Gosford, and on *E. acmenioides* from Glen Innes, Mr. T. W. Taylor. In

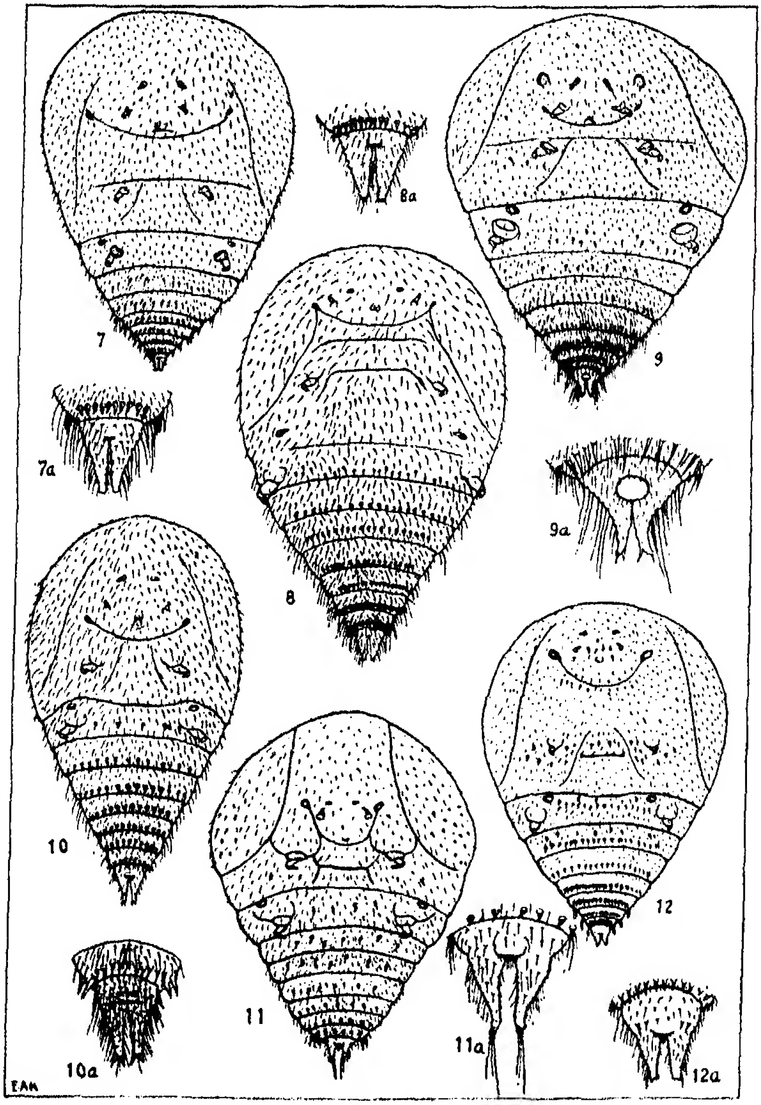
the herbarium of the Botanic Gardens there are specimens on *E. piperita*, Concord, Miss Walker; *E. Camfieldi*, Hornsby, Mr. W. F. Blakely; *E. robusta*, Hill Top, Mr. E. Cheel; *C. virgata*, Gosford, Mr. de Beuzeville; *E. acmenioides*, Uringa, Mr. F. A. Andrews; *E.* sp., Port Macquarie, Forester Brown. The only specimens from out-



Text-figs. 1-6.
1.—*Apiomorpha macqueeni* Froggatt. 2.—*Apiomorpha fusiformis* Froggatt (2*a*, anal segment). 3.—*Apiomorpha longmani* Froggatt. 4.—*Apiomorpha spinifer* Froggatt (4*a*, anal segment; 4*b*, blunt spines on cephalic region). 5.—*Apiomorpha annulata* Froggatt (5*a*, anal segment). 6.—*Apiomorpha umbellata* Froggatt (6*a*, anal segment; 6*b*, bell-shaped appendages on cephalic region).

side the State are from the Dandenong Ranges, Victoria, collected by Mr. C. French, Jr.

The male and female galls are gregarious, often aborting the leaves and twigs of an infested tree. The male galls, scattered over the leaves, are cylindrical tubes with the apex dilated. The female galls have two distinct forms, but all



Text-figs. 7-12.

7, 7a.—*Apiomorpha dumosa* Froggatt. 8, 8a.—*Apiomorpha minor* Froggatt. 9, 9a.—*Apiomorpha excupula* Fuller. 10, 10a.—*Apiomorpha globosa* Froggatt. 11, 11a.—*Apiomorpha pileata* Schrader. 12, 12a.—*Apiomorpha dipsaciformis* Froggatt.

conform to the one type on each tree. They are sessile, green, and in the first type elongate-oval, rounded to the apex which is deeply truncate, with the sides forming two folds or lips with an elongate slit between them, instead of the circular apical orifice of most species. The second form is squat and oval, with the summit more deeply cut into on either side of the opening. In the early stages of their development the summit of each gall is covered with a tailed cap, often tapering out several inches in length; as the gall develops this cap dries and drops off the gall. Schrader figured these galls in his original description of the type. I give a drawing of the oval variety in my Descriptive Catalogue, Part ii, 1921, and Tillyard also figures them (*Insects of Aust. and N.Z.*, Pl. 14).

Female coccid three-fourths of an inch in length. Derm clothed with fine spiny hairs increasing in numbers and length to the tip of the abdominal segments. The whole surface covered with small annular pores, densest on the abdominal segments. A few scattered small lance-shaped spines across the centre of the thoracic segments; 1st and 2nd abdominal segments with scattered lance-shaped spines across the centre; 3rd to 6th banded with chitin and an irregular row of larger lance-shaped spines. Anal segment small with a dark chitinous band on each side coalescing with the base of the anal appendages which are separated from each other by the fringed anal ring; anal appendages peg-shaped, broad at the base, slender, irregularly rounded to the pointed tips which carry a tuft of three or four long hairs.

Group B.

APIOMORPHA URNALIS Tepper. Text-figs. 26, 26*a*.

The type specimen of this dainty jug-shaped gall was described from South Australia. We now know it as one of the inland species common upon various species of the dwarf gums of the Mallee scrubs.

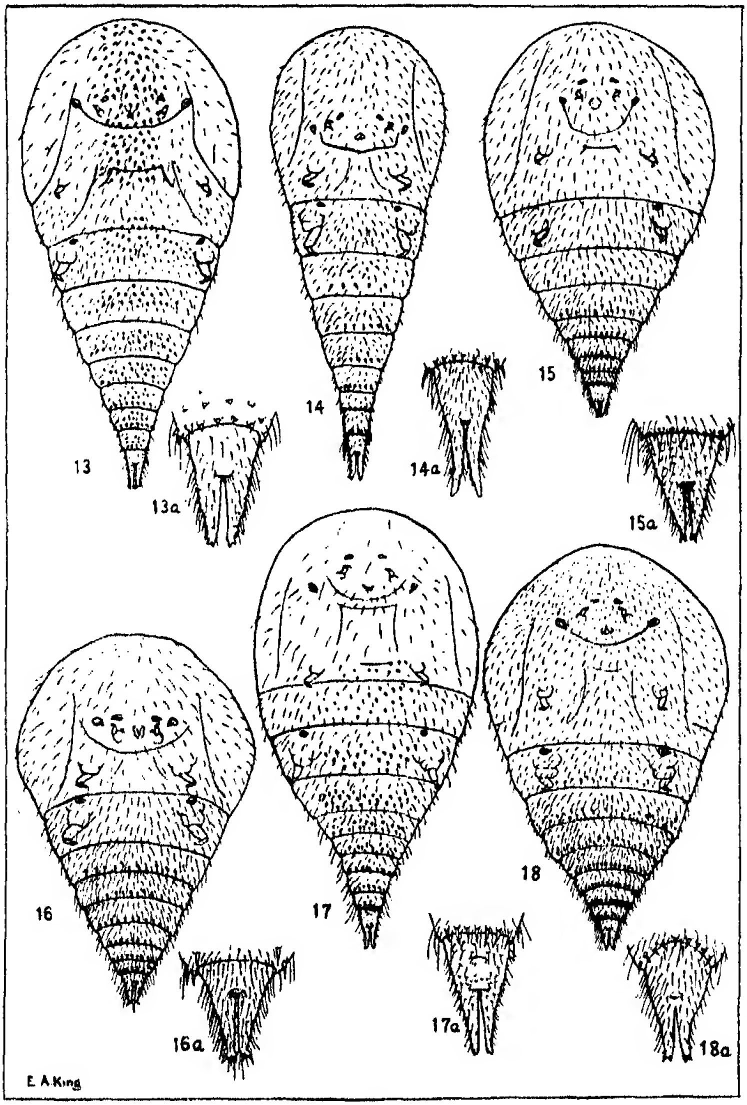
The range and list of eucalypts it infests I have recorded (These PROCEEDINGS, 1930), with a photograph showing the variations in the form of the female galls. The male galls are of the typical cylindrical form, and are scattered over the twigs and foliage among the female galls.

The female coccid is very slender, with the base narrow, round, and swelling out on the sides in a line with the second pair of legs, the first four abdominal segments with the outer margins uniform, with the 5th and 6th narrow and rounded, 7th spindle-shaped, tapering to the apex, longer than the 5th and 6th combined. Anal appendages not coalescing with the anal segment, dark reddish-brown, long and slender, open at the base, and curving outward, bifid at the slender tips.

Derm with a yellow chitinous patch in the centre of the cephalic fold covered with small slender lance-shaped spines of variable sizes, which are encircled by ten irregularly rounded dark-brown lobes, with three irregular shaped spined black lobes below, two above, and one below the second pair of legs. The thoracic segments clothed with scattered, very fine spiny hairs. The legs rather slender, dark brown with a short narrow bar of the same colour on each side of all the segments. The first three abdominal segments broadly banded with fine spiny hairs, and a few small stout spines in the centre; 4th to 6th with similar hairs and a regular band of small lance-shaped spines; 7th deep yellow, with very fine spiny hairs lightly scattered all over the surface and a few long slender spines in the centre.

APIOMORPHA MACQUEENI Froggatt. Text-fig. 1.

This species, which is apparently confined to the southern forest land of southern Queensland, has only been recorded upon the branchlets of the narrow-leaved ironbark, *Eucalyptus pilligaensis*.



Text-figs. 13-18.
13.—*Apiomorpha ovicola* Schrader (13*a*, anal segment). 14.—*Apiomorpha pedunculata* Fuller (14*a*, anal segment). 15.—*Apiomorpha strombylosa* Tepper (15*a*, anal segment). 16.—*Apiomorpha variabilis* Froggatt (16*a*, anal segment). 17.—*Apiomorpha withersi*, n. sp. (17*a*, anal segment). 18.—*Apiomorpha maliformis* Fuller (18*a*, anal segment).

The female gall is very variable in form, and since it was described in These PROCEEDINGS in 1929, I have had a large series from Mr. Macqueen, some of which have a wonderful resemblance to a fig, others to a top; others are almost spindle-shaped, but all have the typical ragged apex.

The male galls which have also come to hand are of the normal type of small cylindrical tubes, scattered over the surface of the leaves. The extraordinary elongation of the anal segments, particularly the anal one, which is quite distinct from the slender flattened anal appendages, is well depicted in Miss King's drawing.

APIOMORPHA UMBELLATA Froggatt. Text-figs. 6, *6a*, *b*.

The type specimens were collected by Mr. J. L. Boorman upon a Mallee gum, *Eucalyptus dumosa*, near Cobar, N.S.W. It has since been sent from Griffith, N.S.W., upon *E. oleosa*, by Mr. W. D. Campbell. Another unique specimen on the branch of a Mallee gum comes from Coolebah, N.S.W., where several galls of this species are growing side by side with other galls of *Apiomorpha conica*. Professor J. B. Cleland has lately sent it from Flinders Range, South Australia, upon *E. odorata*.

The female galls, usually in clusters upon a branchlet, are sessile, narrow at the base, cylindrical, swelling out to the truncate apex, which is rugose, the small apical orifice in the centre.

Female coccid very slender, the cephalic segment rounded, clouded with yellow in the centre, and covered with fine pointed spines, encircled by a band of dark brown lobes, three on either side and four below, besides which there are three black, irregularly spined lobes, two above and one between the second pair of legs. There is a pair of short brown bars on each segment; the thoracic ones clothed with fine spiny hairs and a few short small spines; 1st to 3rd abdominal segments clothed with fine spiny hairs and a few short spines; 4th and 5th with similar spiny hairs and a band of fine spines; 6th contracted and rounded on the sides with the short spines forming a band across the lower margin. The anal segment yellow, very long, slender, spindle-shaped, narrow to the apex, clothed and fringed with fine spiny hairs, not coalesced with the anal appendages which open from the base and are dark brown, very long, irregularly rounded, slender, rugose and bifid at the tips.

APIOMORPHA SLOANEI Froggatt.

The gall and adult coccid of this species are figured and described in These PROCEEDINGS, 1898. The type specimens were collected by Mr. T. G. Sloane on an unidentified eucalypt in the Wagga district, N.S.W. I have never seen any other specimens.

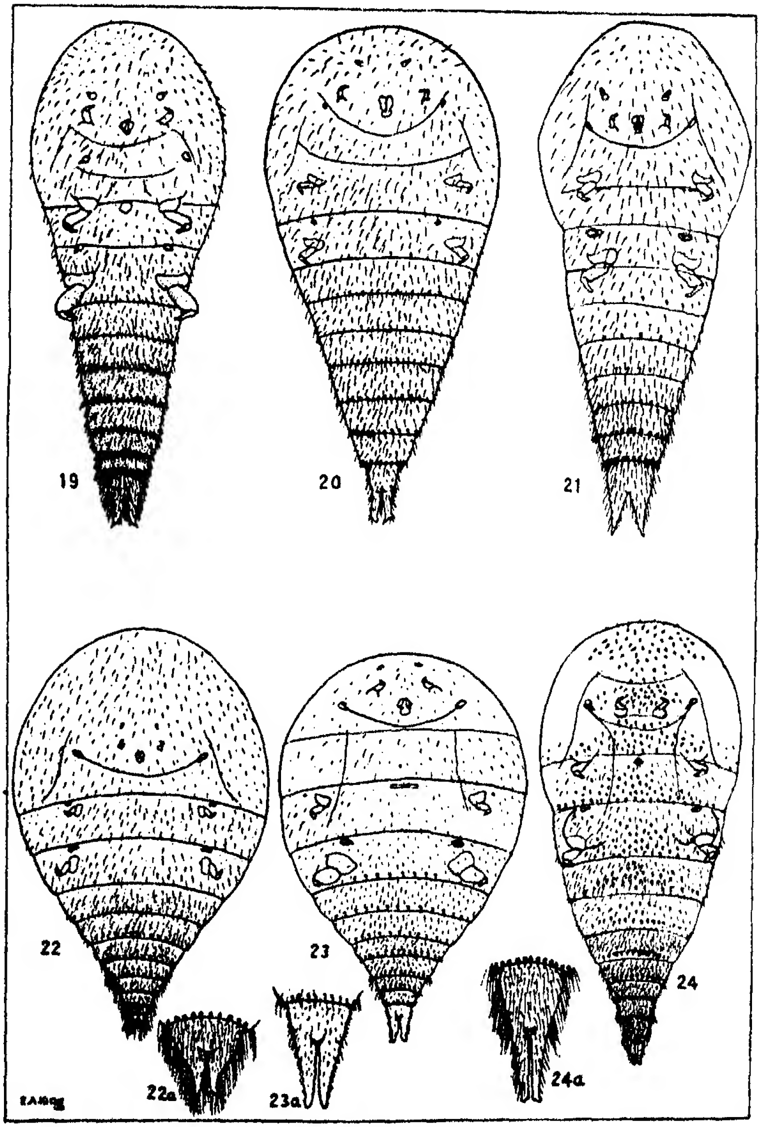
The elongate cylindrical galls have a general appearance similar to those of *Apiomorpha pedunculata*. The enclosed coccid, however, belongs to the group with the slender form, in which the anal segment is longer than the rest of the abdominal segments combined, not coalesced with the anal appendages which open from the base and are long and slender.

Group C.

APIOMORPHA PHARETRATA Schrader. Text-figs. 27, *27a*.

This "cockscomb" gall was described and figured by Schrader in 1862 upon *Eucalyptus corymbosa* growing in the vicinity of Sydney, and is recorded upon

several other species. It has a wide range, a record of which is given in my paper in These PROCEEDINGS, 1930, where it is figured. There is another figure in my Descriptive Catalogue, Pt. ii (*Science Bulletin* 18, Department of Agriculture of N.S.W.).



Text-figs. 19-24.

19.—*Apiomorpha conica* Froggatt. 20.—*Apiomorpha thorntoni* Froggatt. 21.—*Apiomorpha attenuata* Froggatt. 22.—*Apiomorpha munita* Schrader (22*a*, anal segment). 23.—*Apiomorpha bäuerleni* Froggatt (23*a*, anal segment). 24.—*Apiomorpha helmsi* Fuller (24*a*, anal segment).

The female galls produced upon the leaves often springing from the midrib and aborting the foliage. The gall is oval, with the apex truncate. The male galls consist of a mass of coalesced tubes turned down and enfolded in a smooth rounded mass of tissue which springs out of the side of the female gall and is concave on the gall-tube side, and many times the size of the half-hidden female gall.

Female coccid turbinate, 10 mm. in length. Derm lightly clothed with fine spiny hairs, a slight chitinous fold between the second pair of legs. 1st and 2nd abdominal segments covered with longer spiny hairs and a few scattered small lance-shaped spines; 3rd to 5th with an open row of small lance-shaped spines across the centre, but not extending to the outer margins; 6th with a reddish chitinous band across the lower margin, fringed with lance-shaped spines. Anal segment cone-shaped, apical half reddish-brown, truncate on the ventral side which bears the anal ring fringed with hairs. Anal appendages reddish-brown, not coalescing with the dorsal surface of the anal segment, slender, pointed and curving outward.

APIOMORPHA THORNTONI Froggatt. Text-fig. 20.

This species is found upon the foliage of *Eucalyptus piperita* in the Newcastle district and in the vicinity of Sydney. I have it from Guyra, N.S.W., upon *E. macrorrhyncha*, Rev. E. N. McKie; and *E. amygdalina*, Dandenong Ranges, Victoria, Mr. C. French, Jr. The galls are compound and differ from those of *Apiomorpha pharetrata* in the female galls being smaller, ribbed on the sides, and the attached mass of male galls being much more irregular in form and wrinkled. A description of the immature female gall and coccid is given in my paper in These PROCEEDINGS, 1930.

Female coccid turbinate, tapering to apex. Length, 8 mm. Derm thin, with the cephalic and thoracic segments lightly clothed with fine spiny hairs, 1st and 2nd abdominal segments with an irregular band of fine lance-shaped spines interspersed with spiny hairs; 3rd to 6th with a regular row of lance-shaped spines along the lower margin, on the 6th a narrow chitinous band carries the spines. Anal segment conical, with the exception of the basal margin reddish-brown; in general structure like that of *Apiomorpha pharetrata*, but the anal appendage rugose on the ventral surface, and curving outward. Anal ring on the ventral side of the tip of the anal segment.

APIOMORPHA ROSAEFORMIS Froggatt.

This beautiful compound gall is a very rare species and in the three specimens examined the spindle-shaped female galls contained nothing but the remains of the female coccid. The type specimen came from Wingham, Manning River, N.S.W. Two other specimens were collected by Professor J. B. Cleland on a stringybark, *Eucalyptus capitata*, at Neutral Bay, near Sydney.

I figured the type specimen in These PROCEEDINGS, 1895, and in 1930 I gave a figure showing the slender female gall with its attached mass of pink-tinted disk of male galls.

APIOMORPHA SPINIFER Froggatt. Text-figs. 4, 4*a*, *b*.

This species was described in my paper in These PROCEEDINGS, 1930, from specimens upon an undetermined species of *Eucalyptus* from Stanthorpe, Queensland. These galls were very like those of *Apiomorpha fusiformis*, but more trun-

cate at the apex. Since this was described I have received a fine series of this species from Portland, N.S.W., from Archdeacon Haviland, also on an undetermined species of *Eucalyptus*.

The male galls appear to be rather short and squat, with the apex swollen out into a rounded lump deeply depressed in the centre, but are much aborted by chalcid parasites, which also have infested many of the adult females in the galls. The female galls are in threes and fours along the midrib of the leaf, 10 mm. in height and 4 mm. in diameter. They are very irregular in form and colour, varying from green to brown and often blackened with fumagine. The galls are narrow at the base, irregularly oval in form and not so slender as in the type specimens, but the apex is ringed in the same manner.

The female coccids have the cephalic spines very well defined, varying from two to four in number.

APIOMORPHA FUSIFORMIS Froggatt. Text-figs. 2, 2*a*.

This species was described in my paper in These PROCEEDINGS, 1930. It comes from Queensland, and the type is in the Queensland Museum. The anal ring is fringed with fine hairs, and occupies the ventral side of the anal segment.

Group D.

APIOMORPHA OVICOLA Schrader. Text-figs. 13, 13*a*.

This is an inland species found upon the branchlets and not uncommon on the flower buds of the red gum, *Eucalyptus rostrata*, and as this gum tree is found along the edges of all the inland rivers and water-courses in all parts of Australia, it probably has a very wide range. The type was described by Schrader from the vicinity of Sydney. I have specimens, usually solitary, upon *Eucalyptus microtheca*, Narrabri, Mr. Gordon Burrows; *E. siderophloia*, Gilgandra, Mr. G. Withers; *E. crebra*, Dubbo, W.W.F.; *E. fructorum*, Griffith, Mr. W. D. Campbell; *E. largiflorens*, Curra Curra, Mr. J. H. Maiden. From Queensland on *E. paniculata*, Mr. A. M. Rankin. From Victoria on *E. melliodora*, Stawell, Mr. C. Daley. From South Australia upon two mallee gums, *E. incrassata* and *E. gracilis*.

Male galls small, cylindrical, dilated at the apex, scattered over the leaves and branchlets.

Female galls broadly oval, green and smooth, walls solid, apex slightly depressed, with small circular apical orifice. When infested with phytophagous inquilines feeding in the tissue of the young galls, they often become aborted and vary in form. Tepper (*Trans. Roy. Soc. S. Australia*, 1893) described and figured two of these aborted forms under different names.

Female coccid slightly less than an inch in length. Derm thin and clear, slightly chitinous on the abdominal segments, and a narrow band between the legs. The whole surface clothed with scattered long spiny hairs; the central area of the cephalic and thoracic segments covered with short, dark-brown, slightly curved, rose-shaped thorns which, upon the 1st to 3rd abdominal segments, are in more uniform bands and extend across the segments; 4th to 6th segments with the whole surface covered with these spines, with the chitinous bands covered with very small spines. Anal segment short, coalescing with the anal appendages, truncate at base, both very rugose, the anal segment covered with fine spines springing from little bosses. Anal appendages long, in contact from the base, with the tips bifid.

APIOMORPHA HELMSI Fuller. Text-figs. 24, 24*a*.

The type specimens were taken from an undetermined species of eucalypt near Perth, W. Australia. I have a fine series in groups of two or three formed upon the flower buds of *Eucalyptus redunca* collected by Mr. J. Stair, near York, W.A.

The male galls are scattered over the surface of the leaves. They are of the usual tubular form with the apex dilated, but have the outer surface ribbed and are usually of a yellow colour.

The female galls are sessile, elongate-oval in form, narrow at the base, with from five to seven ridges or angles extending up to the apex, which is arcuate on the edges, convex in the centre with a little projecting cone round the apical orifice.

Female coccid turbinate. Derm slightly opaque, legs and apical abdominal segments brown, anal appendages black. The whole of the dorsal surface clothed with fine spiny hairs increasing in size and numbers on the terminal abdominal segments. The centre of the cephalic and thoracic segments covered with short dark-brown thorn-shaped spines; 1st and 2nd abdominal segments with the central area covered with similar spines; 3rd and 4th with the spines in a transverse row; 5th and 6th with the spines in contact at base along the apical margin. The anal segment rounded on the sides, fringed with fine hairs, coalescing with the slender anal appendages which are rugose on the outer margins, almost in contact along the inner edges and terminating in a fine point turning outward.

APIOMORPHA WITHERSI, n. sp. Text-figs. 17, 17*a*.

This is an interesting species which I have received from two localities upon the narrow-leaved ironbark, *Eucalyptus pilligaensis*, first from Mr. G. Withers, Gilgandra, N. S. Wales, and the second lot from Mr. J. Macqueen, Millmerran, Southern Queensland. At first sight the female galls might be taken for a small variety of *Apiomorpha ovicola*, but the apex is generally more depressed and they are usually gregarious, several in a row upon the branchlet.

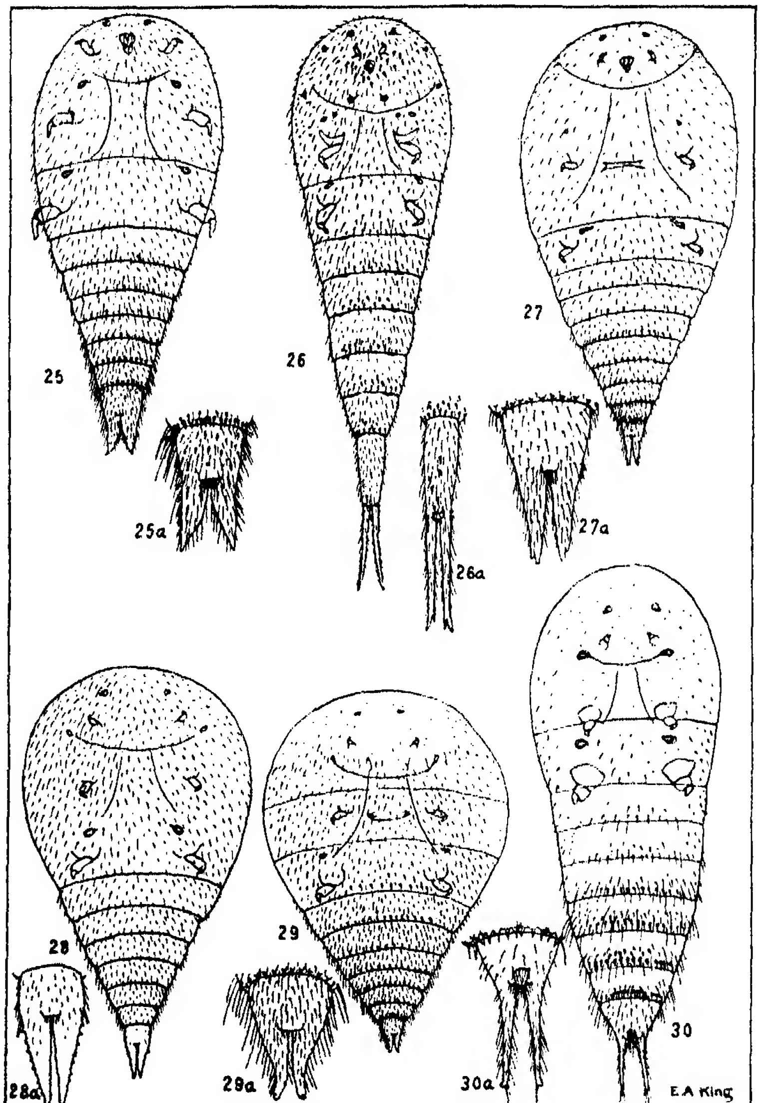
Male gall unknown.

Female coccid light brown, with the external appendages yellowish-brown. The antennae large, broad at base, tapering to the tip, apparently six-jointed; the legs large, the third pair very finely shagreened; thoracic spiracles large, irregularly rounded. The derm lightly clothed with fine hairs on the cephalic and thoracic segments which are more spiny and abundant on the abdominal segments. The 3rd thoracic and 1st and 2nd abdominal segments covered with scattered, dark-brown, small, sharp, thorn-shaped spines, which on the 3rd to 5th abdominal segments form a regular band across the centre, with a cluster of three or four spines in the centre above the regular band; 6th with a band of similar spines along the lower margin. The anal segment long, rounded and rugose on the sides, coalescing with the anal appendages which are slender, finely serrate on the outer margins and separated from each other on the inner margins which are smooth; the tips slightly bifid, turning outward. Anal ring on a chitinous ridge at the base of the anal appendages.

APIOMORPHA FLORALIS Froggatt.

The gall is large, oval and resembles that of *A. ovicola*, but the apex, instead of being rounded, has a distinct raised ring round the apical orifice. The type was growing from a flower bud, *Eucalyptus* sp., and comes from Central Australia.

The general form of the coccid is like that of *A. ovicola*, but the dark thorn-shaped spines down the centre of the cephalic and thoracic segments are much more closely grouped together, forming a continuous, broad, parallel band, not



Text-figs. 25-30.
25.—*Apiomorpha frenchi* Froggatt (25*a*, anal segment). 26.—*Apiomorpha urnalis* Tepper (26*a*, anal segment). 27.—*Apiomorpha pharetrata* Schrader (27*a*, anal segment). 28.—*Apiomorpha fletcheri* Fuller (28*a*, anal segment). 29.—*Apiomorpha sessilis* Froggatt (29*a*, anal segment). 30.—*Apiomorpha duplex* Schrader (30*a*, anal segment).

extending much beyond the base of the legs; on the abdominal segments the spines are more scattered and numerous. The outer margins of the anal segment and anal appendages with the marginal spines larger, but very irregular, the tips similar and bifid.

I have only had the single type specimen.

Group E.

APIOMORHA FLETCHERI Fuller. Text-figs. 28, 28*a*.

This is a very remarkable form of gall structure; the presence of the coccids produces large irregular gouty swellings on the branches. On the surface of these are depressions varying in number from two to five according to the size of the aborted tissue. Over these indentations is a small shred of dead bark, beneath which is the tip of the gall encircling the small circular apical orifice. The real gall consists of this cap which is a thin hard wooden funnel forming a detachable lid fitting over the basal gall chamber containing the coccid. This is simply an oval cavity in the solid mass of aborted wood tissue. The male galls are just as remarkable, masses of tiny pink tubes covering the surface of the leaf. They were described and figured in my paper in These PROCEEDINGS, 1930.

It is also interesting to note that they infest gum trees of such distinct species as the red gum with its smooth bark, and the red box growing on the inland rivers. Since my previous paper I have had specimens of this gall from Western Australia.

Female coccid with the cephalic and thoracic segments broad and rounded; the abdominal ones contracted and tapering, rounded on the sides and thickly coated with chitin, the anal one and anal appendages black and rugose. The derm covered with very fine spiny hairs; the abdominal segment thickly covered with fine spiny hairs springing from little bosses, but there are no large distinctive spines like those found on the abdominal segments of all other known species of this genus. The anal segment and anal appendage coalesced form a long lance-shaped tip to the abdomen; the latter finely serrate on the outer edges, with the tips pointed and opening out.

Group F.

APIOMORPHA DIPSACIFORMIS Froggatt. Text-figs. 12, 12*a*.

The type specimen was figured and described in These PROCEEDINGS, 1895; the galls were perfect, with the whole of the outer surface covered with fine filaments, which curled downward just like a diminutive teasel.

Specimens received from Queensland on *Eucalyptus pilligaensis* were much more matured and had lost much of their spiny covering. These were figured in my paper in These PROCEEDINGS, 1930, together with the male galls.

Female coccid broad rounded, the apical abdominal segments reddish-brown, banded with chitin. Derm lightly clothed with fine spiny hairs, and annular pores thickest upon the basal half of the abdominal segments; a few small lance-shaped spines on the cephalic fold near the base of the antennae, and irregular bands of larger lance-shaped spines upon the 2nd and 3rd thoracic segments; the 1st and 2nd abdominal segments with similar spines on basal bosses, 3rd to 6th banded with chitinous plates bearing a row of stouter spines with the annular pores showing through the chitin and very fine spines over the apical portion. Anal segment very small and narrow, coalescing with the stout peg-shaped anal appendages, which are broadest at the base, open in the centre, rounded and rugose on the outer

sides, bifid at the tips and fringed with fine hairs. Anal ring chitinous, indistinct. In most species the number of segments in the antennae is difficult to determine, but in this and the following species they are well defined.

APIOMORPHA EXCUPULA Fuller. Text-figs. 9, 9*a*.

This species is confined to New South Wales; I described the male galls and figured them with the female galls in These PROCEEDINGS, 1930.

Female coccid broadly rounded to the abdominal segments. Length, 13 mm. Derm slightly opaque with the last four abdominal segments banded with chitin, reddish-yellow, the whole surface clothed with fine spiny hairs, and annular pores, the latter thickest on the abdominal segments. A few small lance-shaped spines on the cephalic fold, and irregularly scattered over the last two thoracic segments; 1st to 3rd abdominal segments thickly covered with fine spiny hairs and a band of long slender lance-shaped spines, 4th to 6th fringed with a band of long lance-shaped spines. Anal segment very small, coalescing with the anal appendages, which are broad at the base, curving outward into peg-shaped bifid tips, rugose, open on the inner margins, with a tuft of long hairs on either side Anal ring at base of anal appendages chitinous and indistinct.

Group G.

APIOMORPHA PEDUNCULATA Fuller. Text-figs. 14, 14*a*.

This fine species which varies somewhat in both form and size, is recorded upon a number of different species of Eucalypts and has a wide range over southern and eastern Australia.

In the vicinity of Sydney it is found upon *Eucalyptus viminalis* and *E. saligna*; Moira, Murray River, on *E. rostrata*; Lansdown, N. S. Wales, on *E. punctata*, Mr. A. C. McIvor; Gilgandra, *E. amplifolia*, Mr. G. Withers. From Queensland, at Imbil, on *E. punctata*, Mr. A. M. Rankin. From South Australia on *E. leptophylla*, Encounter Bay, Professor J. B. Cleland. From Victoria on an undetermined eucalypt, Mr. C. French, Jr.

Male galls of the typical tubular form with the apex dilated are scattered over the foliage.

The female gall, springing from the branchlet in a slender circular stem, swells out into an elongate-oval gall, truncate at the tip. Sometimes solitary, at other times in clusters of three or four.

Female coccid rounded at base with the segments tapering to the apex, but of uniform width. Length, 25 mm. Derm slightly opaque, last three abdominal segments and anal appendages chitinous, the latter black. The whole surface thickly covered with very fine small slender spines and annular pores. Abdominal segments banded with longer slender spines, with a few short conical spines on the 1st abdominal segment, 2nd and 3rd with an irregular band of conical spines, 4th to 6th with a row of larger conical spines in the centre, not reaching to the outer edges. Anal segment coalescing with the long awl-shaped anal appendages, rounded at the base, outer edges fringed with hairs and slender spines, in contact at the base, opening out into slender irregular lance-shaped tips.

APIOMORPHA LONGMANI Froggatt. Text-fig. 3.

This species is described, and the galls figured in my paper in These PROCEEDINGS, 1930. The type is in the Queensland Museum. The female coccid is about

9 mm. in length. The cephalic and thoracic segments rounded to the abdominal segments, which are contracted and narrow from the second segment. Anal segment rounded at the base, coalescing with the stout lance-tipped anal appendages which are open from the base, curving outward, rugose and spined on the outer margins.

APIOMORPHA FRENCHI Froggatt. Text-figs. 25, 25*a*.

This species was described in my Descriptive Catalogue (*Science Bulletin* 18, Department of Agriculture, N. S. Wales, 1921). The type specimens were collected by Mr. C. French, Jr., on the branchlets of a red gum, *Eucalyptus rostrata*, growing on the banks of the Werribee River, Victoria. I have since had a large series in all stages of development from the same locality.

The male galls are very numerous on the leaves and branchlets among the female galls. They are of the typical cylindrical form, but rather short, with the apex broadly dilated.

The female galls single or clustered together in groups on the branchlets, sessile, cylindrical, with the apex truncate, centre slightly convex, with the apical orifice small. The immature galls are green, but as they mature they change to brown, and in old specimens crack into fine rings on the surface.

Female coccid 11 mm. in length; abdominal segments contracted, reddish-brown, banded with chitin, anal segment and anal appendages black. Derm lightly clothed with very small short spiny hairs, forming bands across the first two abdominal segments; 3rd with an irregular band of lance-shaped spines in the centre, 4th to 6th with a regular band of larger lance-shaped spines. Anal segment rounded at base, coalescing with the anal appendages, which are broad at the base, opening out and rounded, forming broad lance-shaped tips.

APIOMORPHA CONICA Froggatt. Text-fig. 19.

This somewhat variable gall has a wide range over eastern and southern Australia, but I have not seen specimens from Queensland. In the vicinity of Sydney it is found upon *Eucalyptus robusta*, *E. viminalis* and *E. Deanei*; from Guyra, N. S. Wales, on *E. Nicholi*, Rev. E. N. McKie; Glen Innes in the north and Captain's Flat in the south on undetermined eucalypts. From Victoria upon *E. Gunni*, Hamilton, and *E. regnans*, Croydon, Mr. C. French, Jr. It was described from South Australia by Mr. J. G. O. Tepper. In the herbarium of the Sydney Botanic Gardens there are specimens from Broken Hill on *E. dumosa*, Mr. A. Morris; Cobar, *E. dumosa*, Mr. J. C. Boardman; East Mirool, *E. oleosa*, Mr. Campbell; Bellerive, W. Australia, *E. viminalis*, Mr. J. H. Maiden; Kaneara, Victoria, *E. bicolor*, Rev. W. W. Watts.

Male galls of typical form, tubular with dilated apex, scattered about over the surface of the leaves.

Female galls broadly oval, with the conical apex distinctly ringed round the apical orifice, grouped in bunches or single on the branchlets. A plate is given in my Descriptive Catalogue, 1921, showing the variation in form of this gall.

Female coccid with the derm clothed with fine spiny hairs increasing in size and numbers to the abdominal segments. Length, 20 mm. Annular pores present, thickest on the abdominal segments; the 3rd thoracic and 1st abdominal segments covered with stiff spiny hairs, 2nd to 6th abdominal segments banded with chitin, dull yellow, clothed with fine slender spines and banded with stout lance-shaped

spines, in the last three forming a close row along the lower margin. Anal segment merged into the anal appendages, rounded at the base, short and broad, terminating in two broad pointed fingers opening outward.

APIOMORPHA ATTENUATA Froggatt. Text-fig. 21.

This species was described from a gall from a spray of slender fusiform galls produced on the flower-buds of an undetermined species of *Eucalyptus* which came from South Australia, without any definite locality. There is a drawing of this spray of galls in my original description in These PROCEEDINGS, 1898, and a photograph in my Descriptive Catalogue (Department of Agriculture, N. S. Wales, *Science Bulletin* 18).

Female coccid with the cephalic and first two thoracic segments rounded, contracted on the upper margin of the third thoracic segment which, with the first abdominal segment, is broad and of uniform width, the 5th and 6th abdominal segments reddish-brown, chitinous, anal segment and anal appendages dark reddish-brown. Length of female coccid, 9 mm.

Derm clothed with fine spiny hairs, 1st to 3rd abdominal segments with a few scattered small lance-shaped spines across the centre interspersed with long spiny hairs, 4th to 6th with the lower margin fringed with a row of stout lance-shaped spines. Anal segment merged into the anal appendages which are broad and rounded at the base, divided and curving outward into lance-shaped tips, fringed on the sides with fine hairs.

Considering the slender form of the gall, one would expect to find the enclosed coccid of the slender type with attenuated abdomen, instead of this rather stout coccid with thickened anal appendages.

Group H.

APIOMORPHA GLOBOSA Froggatt. Text-figs. 10, 10*a*.

The type specimens were collected on the branchlets of the red gum, *Eucalyptus rostrata*, near Hay, N. S. Wales. I have lately received a fine series from Gilgandra, N.S.W., on *E. dealbata*, from Mr. G. Withers. The female galls dull brown when mature, sessile and usually solitary, rounded and slightly concave on the summit.

Female coccid pale-yellow, semi-opaque, in old specimens the abdominal segments reddish-yellow and the anal appendages black; broadly turbinate. Length, 10 mm. Derm clothed with rather long spiny hairs thickest on the sides of the cephalic and thoracic segments, 1st and 2nd thoracic segments with an irregular line of very small lance-shaped spines across the centre; 1st to 6th abdominal segments with a scanty line of small lance-shaped spines across the centre of the segments. These spines, opening out at the base, might be likened to arrow heads, particularly on the 4th and 5th segments. Anal segment and anal appendages coalesced, fitting close against the 6th segment, truncate and combined, forming an elongated triangle, with the anal ring with a chitinous ridge in the centre. The anal appendages in contact along the inner edges, slender, rugose, the outer edges serrate, with the tips pointed and turning outward.

APIOMORPHA MALIFORMIS Fuller. Text-figs. 18, 18*a*.

This species comes from south-western Australia, where it infests the blackbutt, *Eucalyptus patens*. I have had a fine series of galls from Messrs. Wallace and Stewart from Busselton, and Mr. Kessell from Jarradale and Margaret River,

chiefly upon branchlets, but in one case the galls were half embedded in the bark of a stout sapling gum. Mr. L. J. Newman sent me specimens from near Perth on *E. Toddiana*.

Fuller when describing this species said that the galls were usually found upon the flower-buds of the eucalyptus, but this, I think, is a slip, confounding them with the smaller *Apiomorpha helmsi*, described in the same paper, which is also plentiful in the same localities.

The male galls are small slender tubes, slightly dilated at the apex, which are produced on the surface of the leaves.

The female galls are solid woody masses, apple-shaped, broadly rounded and depressed in the centre at the apex, with the apical orifice in the centre. They are light brown in colour, slightly roughened, and often massed together in groups of three or four; up to 1½ inches in diameter and 1½ inches in height.

Female coccid broadly turbinate, abdomen coming to a point, terminal ones chitinous. Length, 15 mm. Derm clothed with fine spiny hairs, thickest on the abdominal segments, which show annular pores scattered among them; 3rd thoracic and 1st abdominal segments with irregular band of lance-shaped spines, 2nd to 6th with a more regular band of thorn-shaped spines. Anal segment very small, coalesced with anal appendages, rounded on the sides, rugose; anal appendages rugose, in contact on the inner edges, fringed with fine hairs, bifid at tips. Anal ring fringed with fine hairs.

APIOMORPHA STROMBYLOSA Tepper. Text-figs. 15, 15*a*.

This distinctive gall has a wide range over eastern and southern Australia, and infests many different species of eucalypt. In the vicinity of Sydney it is found on *Eucalyptus siderophloia*, the broad-leaved ironbark. The type was described from South Australia on *E. incrassata*; I found it at Euston, N. S. Wales, upon a mallee gum, *E. transcontinentalis*; Ourimbah, N. S. Wales, on *E. punctata*, Mr. de Beuzeville; Imbil, Queensland, on *E. paniculata*, Mr. M. Rankin; W. Australia, *E.* sp., Mr. C. Fuller; Victoria, *E. polyanthema*, Mr. C. French, Jr. The female galls are shaped and have a rough brown surface like a sheoak seed-cone, and on account of their dark colour and size are very noticeable among the foliage. They are sometimes solitary on the stem or branch, or in clusters of three or four. The male galls are irregularly rounded, slender, without the apex dilated, dark reddish-brown; thickly scattered over the surface of the leaves.

Female coccid broadly turbinate, terminal abdominal segments small and barred with chitin. Length, 21 mm. Derm clothed with very long spiny hairs and annular pores, the former forming regular bands across the thoracic segments, the latter very small and most numerous on the thoracic and abdominal segments; 1st abdominal segment with only one or two lance-shaped spines, 2nd with an irregular band of rather long lance-shaped spines, 3rd to 5th with a regular row of similar spines; 6th with fewer spines across the centre. Anal segment truncate at base, sloping in on either side and coalescing with the anal appendage, both rugose, covered with spiny hairs springing from rounded bosses. Anal appendages lance-shaped, open along inner margin, rugose and fringed with fine hairs, bifid at the tips, anal ring indistinct.

APIOMORPHA VARIABILIS Froggatt. Text-figs. 16, 16*a*.

This species is restricted in its range from Sydney to southern Queensland. In the Sydney district it is found upon *Eucalyptus saligna*, *E. Sieberiana*, *E. piperita*.

E. Camfieldi and *E. umbra*. At Gosford, N.S.W., on *E. pilularis*, Mr. A. Murphy; Port Macquarie, *E.* sp., Forester Brown. From Queensland, Imbil, on *E. acmenioides*, Mr. M. Rankin.

This female gall is sessile and consists of two parts. The basal portion consists of a solid woody mass, covered with a smooth green skin which contracts about two-thirds from the base, and rises like a rounded dome over the basal gall. It has a ragged opening on the summit, above the irregular cavity, between it and the apical orifice into the gall chamber. Though this is not an uncommon species, I have seen no male galls.

Female coccid broadly turbinate, 13 mm. in length. Pale yellow with the abdominal segments darkest. Derm clothed with scattered hairs and annular pores. The 3rd thoracic segment thickly covered with long spiny hairs interspersed with fine short spines; 1st to 3rd abdominal segments covered with similar spiny hairs and small lance-shaped spines; 4th to 6th with large spines forming a regular band across the lower margin of the segments. Anal segment coalescing with the anal appendages and combined forming an elongate triangle, slightly rounded at the base, covered with fine spines, slightly rugose on the outer margins and fringed with fine hairs; the anal appendages slender, almost in contact along the inner margins, and the tips bifid, the outer point largest and turning outward.

APIOMORPHA BÄUERLENI Froggatt. Text-figs. 23, 23*a*.

The type specimens were collected at Ballina, N.S.W., upon an undetermined species of Eucalyptus. I have never seen any more specimens. Male gall unknown.

Female galls are sessile, single or in groups of two or three upon the branchlets. They are rounded, slightly ribbed on the sides, and depressed on the apex; the walls are double round the coccid chamber, the outer one soft, over a hard woody sheath round the enclosed coccid. This often produces a ragged edge round the apical orifice.

Female coccid broadly turbinate, much wrinkled, with the abdominal segments coming to a fine point, 12 mm. in length. Derm slightly chitinous, anal segments yellow, very lightly clothed with short spiny hairs; 2nd and 3rd thoracic segments bearing a few small blunt spines; 1st and 2nd abdominal segments with irregular bands of longer sharp lance-shaped spines; 3rd to 6th with the spines increasing in size and forming regular rows across the lower margins. Anal segment coalescing with the anal appendages, tapering to a slender point, serrate along the outer margins, in contact on the inner margins and slightly bifid at the tips. Anal ring showing on a chitinous ridge at the base of the anal appendages.

Group I.

APIOMORPHA MUNITA Schrader. Text-figs. 22, 22*a*.

This is the most variable form of gall, and one of the widely distributed species of the genus. The original specimens described by Schrader were collected near Sydney.

I have specimens upon *Eucalyptus saligna*, *E. piperita*, *E. siderophloia* and *E. paniculata* from the vicinity of Sydney; from Gilgandra, N.S.W., on *E. crebra* and *E. sideroxylon*, Mr. G. Withers; *E. leptophylla*, Euston, N.S.W., W.W.F.; from Victoria on several undetermined species of eucalypt; from Western Australia, *E.* sp., Mr. L. J. Newman; from Cairns, N. Queensland, Mr. E. Jarvis.

In the Herbarium of the Botanic Gardens, Sydney, there are specimens from Lockhart, N.S.W., on *E. melliodora*, Merool, on *E. oleosa*, Urunga, on *E. grandis*, Pine Creek, on *E. fructorum*; Murray Bridge, S. Australia, on *E. incrassata*.

Male galls irregular, slender, rounded tubes, massed together in great numbers upon the branches and often formed upon the horns and sides of the adjacent female galls.

The typical female gall springs from the branch with a rounded base with the apical margin angulated, and each corner produced into a long projecting slender horn. The variations in both the male and female galls are illustrated on plates 132 and 134 in my Descriptive Catalogue.

Female coccid turbinate, abdominal segments chitinous, small. Length, 20 mm. Derm clothed with a few spiny hairs and many very small lance-shaped spines of different sizes, forming with the spiny hairs irregular bands across the thoracic and abdominal segments; 4th to 6th abdominal segments closely covered with rounded chitinous bosses from which small spines spring. Anal segment short and broad, rounded on the sides, coalesced with the anal appendages which are short, broad at the base, tapering to the tips which turn outward and are bifid. The whole rugose and fringed with fine hairs.

APIOMORPHA HILLI Froggatt.

This curious gall was described and figured in my Descriptive Catalogue, Pt. ii (Department of Agriculture, N.S.W., *Science Bull.* 18, 1921). It is found on the woollybutt, *Eucalyptus miniata*, in the vicinity of Darwin, North Australia.

The remarkable likeness of the female gall to the seed capsule of its host tree is shown in the plate in my Catalogue. Somewhat like the gall of *Apiomorpha variabilis*, the basal portion is solid wood enclosing the gall chamber; above this is a cavity surrounded by an outer rim to which coalesces a pointed wooden cap, which cracks off but remains attached on one side as the gall matures.

Adult coccid about half an inch in length, very broad, rounded, and wrinkled, the anal segments very small. Abdominal segments banded with long lance-shaped spines; anal segment coalescing with the short anal appendages, rounded at the base, broad and tapering to the tips which turn outward. Fringed with fine hairs.

APIOMORPHA SESSILIS Froggatt. Text-figs. 29, 29a.

This is a rare species; the type specimens were collected at Newcastle, N.S.W., on an undetermined species of *Eucalyptus*. Several other specimens were collected near Hornsby on *Eucalyptus deformis* by Messrs. Shiress and Blakely, and a single specimen by Miss T. M. Irby at Casino, N.S.W.

Male gall unknown.

Female gall cylindrical, the base buried in a swelling in the stem; the summit truncate, rugose, and the apical orifice in the centre.

Female coccid broadly turbinate, yellow, apical segments chitinous. Length, 10 mm.

Derm clothed with fine spiny hairs springing from small rounded bosses, thickest on the lower thoracic and abdominal segments; 3rd thoracic segment with a few stout conical spines scattered across the centre; 1st to 2nd abdominal segments with a scattered row of small conical spines across the centre, 3rd to

6th with a very close row of similar larger spines, on the 6th along the lower edge. Anal segment short, rounded at the sides, coalescing with the short anal appendages, which are broad at the base, tapering to the pointed tips which turn outward, slightly serrate and fringed with fine hairs. Anal ring obscure, at the base of the anal appendage.

Apiomorpha minor Froggatt. Text-figs. 8, 8a.

The type specimens were collected at Wollongong, N.S.W., upon *Eucalyptus haemastoma*. It has been recorded upon the same eucalypt by Mr. D. Shiress, near Sydney; *E. eugenioides*, Hornsby, Mr. Blakely; *E. capitellata*, Neutral Bay, Professor J. B. Cleland; *E.* sp., Guyra, Rev. E. N. McKie. From Victoria, Mr. C. French, Jr., collected it on *E. polyanthema* at Warrandyte.

Male galls upon the foliage rather small, of the typical tubular form, with the apex dilated.

Female galls sessile, oval, broadest at the base, truncate at the apex with the apical orifice in the centre of the concave depression. Generally in clusters of three or four on the branchlets.

Female coccid turbinate, with the abdominal segments small. Length, 12 mm. Derm thickened, yellow, last four abdominal segments banded with chitin; the whole surface covered with short slender spiny hairs springing from circular bosses; a few short spines on the second thoracic segment, with an irregular band across the third thoracic segment; 1st to 3rd abdominal segments with a row of thorn-shaped spines forming a band across the centre; 4th to 6th with the spines forming a closer band across the lower half of the segments. Anal segment coalescing with the anal appendages, rounded at base and sides, rugose, the anal appendages short, broad at the base, tapering to pointed tips which curve outward and are fringed with fine hairs. Anal ring surrounded by a chitinous ridge at the base of the anal appendages.

Apiomorpha dumosa Froggatt. Text-figs. 7, 7a.

This species was described and the galls figured in my paper in These Proceedings, 1930. It is found in the Mallee scrub and the oval sessile gall has nothing very characteristic about it. The enclosed coccid, however, has distinct specific characters and falls into this group. The derm is chitinous with no large spines on the thoracic segments, with the 2nd to 6th abdominal segments thickly clothed with very fine spines and rows of lance-shaped spines across the apical half of each. Anal segment very small, with the anal appendages small, rounded at the base, tips small, bifid, and curving outward.

Apiomorpha rugosa Froggatt.

This species was described from a number of galls collected upon an undetermined species of eucalypt growing at Ellalong, near Maitland, N.S.W.

The galls are sessile, with the rounded surface furrowed and rugose, the apex slightly depressed, with a circular pit above the apical orifice. The coccid irregularly turbinate, wrinkled, with the abdominal segments small and coming to a fine point, the abdominal segments fringed with fine spines, and the anal appendages and anal segment small, fringed with fine hairs, the former short, broad at base, with the tips tapering to the tips which open out, the sides rugose.

APIOMORPHA ANNULATA Froggatt. Text-figs. 5, 5*a*.

This species was described in my paper in These PROCEEDINGS, 1930, with the galls figured. It comes from Queensland.

The galls and coccid fit into this group. The coccid has the typical distribution of spiny hairs and spines on the dorsal surface, of which *Apiomorpha munita* might be taken as the typical form. The abdominal segments are small, and agree in general form, but the anal appendages are not quite typical as they are not so broad at the base, are more lance-shaped, and do not curve outward so much at the tips. They, however, come nearer this than any other group.

The type is in the Queensland Museum.

A NOTE ON THE LEAF BUDS OF ANGOPHORAS.

By Gladys Carey, B.Sc.

(Four Text-figures.)

[Read 25th November, 1931.]

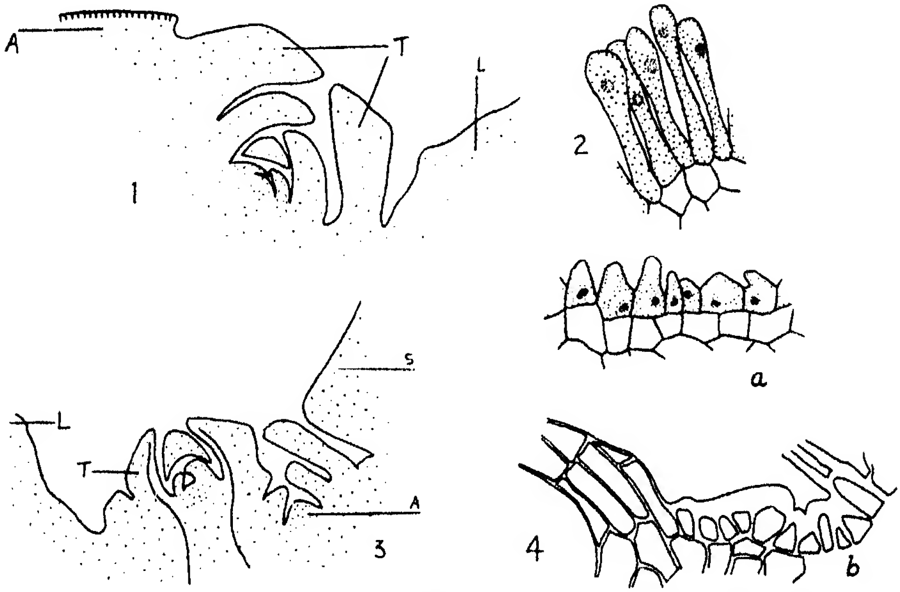
In a recent paper concerning leaf-bud structure in New South Wales perennials (Carey, 1930), the bud of *Angophora lanceolata* Cav. was classed as a microscopic bud which gave rise on expansion to a shoot of a type intermediate between that formed from a scaly bud and that from a naked bud. However, a full description of the bud of *Angophora lanceolata* was not given, it being described "as an ill defined axillary swelling". Further examination shows that this axillary swelling is in reality a deep-seated bud of peculiar type, in which the primordia are well differentiated.

In all species of *Angophora* the leaves are opposite and the inflorescence is borne terminally so that all leaf buds occur in an axillary position. A common feature of this genus is the presence of a second or accessory bud, one occurring in the axil of each leaf, between the growing bud and the stem (Text-fig. 3). This occurrence is general in four of the five species described; it is less usual in *Angophora lanceolata*.

The leaf bud of *Angophora lanceolata* is an invaginated one, the growing apex being depressed as in *Isoetes* (Lang, 1915), only to a less extent (Text-fig. 1). The outer rudiments in the dormant bud each show a conducting strand of spiral elements close to the adaxial surface. The parenchymatous cells contain an abundance of calcium oxalate in the form of druses, and occasionally young schizogenous glands are found. These partially mature structures are the outer transitional forms of the open bud. The term "transitional form" has been applied by Foster (1929) to those structures which occur on the shoot arising from a scaly bud between the true scales and the first true leaf. The writer has applied this term to similar structures occurring on the outside of a bud of the "intermediate" type (Carey, 1930). On the expansion of the bud these transitional forms, although buds appear on their axils, themselves show only a slight degree of development. Passing inwards in the bud each successive pair of rudiments shows less divergence from the meristematic cone. This cone occupies but a small area only a few cells in depth and the elongation zone behind it is very short, with the result that it comes to lie at the bottom of a pit.

The bud is covered by a rubbery secretion of the nature of caoutchouc described by Welch (1923). This secretion helps to mask the bud and make its position in the axil of the leaf indistinguishable. This covering is secreted by the papillate epidermal cells of the foliar rudiments (Text-fig. 2). Similar epidermal cells on the young leaves of *Eucalyptus corymbosa* have already been figured by Welch (1923) and those occurring in *Angophora lanceolata* are mentioned by him.

The epidermal cells found on the outer transitional forms of *A. lanceolata* as seen in Text-figure 2 are more elongated and hair-like than those recorded for *Eucalyptus corymbosa* and occasionally show one or two transverse walls.



Text-fig. 1.—The dormant bud of *Angophora lanceolata*. L, leaf; A, stem apex; T, transitional form. × 40.

Text-fig. 2.—Papillate epidermal cells occurring on the transitional forms of a leaf bud of *Angophora lanceolata*. × 350.

Text-fig. 3.—An expanding bud of *Angophora subvelutina*. L, leaf; S, stem; T, transitional form; A, accessory bud. × 40.

Text-fig. 4.—A. The epidermal cells of a developing primordium of *Angophora cordifolia*. × 350. B. The epidermal cells of a transitional form of *Angophora cordifolia*. × 350.

With the advent of the growing season, rapid division and elongation begins at the apex of the meristematic cone, so that the younger primordia are carried above the level of the outer organs of the bud. As soon as this extension begins the bud becomes quite obvious to the naked eye and assumes the appearance which has already been figured (Carey, 1930).

Angophora subvelutina F.v.M. has a similar but smaller leaf bud than that of *A. lanceolata*. It is covered by the same type of secretion, produced in papillate epidermal cells. An expanding bud of this species is shown in Text-figure 3, together with a dormant accessory bud. The latter is gradually crushed out by the growth of the former. The expanding shoot shows transitional forms similar to those of the shoot of *A. lanceolata*.

A. Bakeri C. Hall and *A. intermedia* D.C. have leaf buds similar to those of *A. lanceolata*.

Angophora cordifolia Cav. has also a hidden bud. The leaf axil is usually flattened and in it occur two buds further apart than in the other types. The outline of the bud is similar to that of *A. lanceolata*, except that the bud is broader

and flatter than in that type. The epidermal cells of the young primordia appear slightly papillate (Text-fig. 4, A), but the outer more mature rudiments of the bud show the development of the emergences and hairs characteristic of the species as is shown in Text-fig. 4, B. The expansion of this shoot has already been mentioned (Carey, 1930).

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NOTES ON NEW SOUTH WALES ORCHIDS.

By the Rev. H. M. R. RUPP, B.A.

(One Text-figure.)

[Read 25th November, 1931.]

ORCHIDS OF THE SOUTH MAITLAND COALFIELDS.—In These PROCEEDINGS, 1930, p. 413, and 1931, p. 133, I have recorded 68 species of orchids from this area. Six more have since been added to the list, as follows:

69. *Bulbophyllum Elisae* F.v.M.—Mrs. C. A. Messmer found this plant during an excursion to Rocky Glen, beyond Mount Vincent.

70. *Thelymitra media* R.Br.—Between Pelaw Main and Mount Vincent, August, 1931 (Mrs. C. A. Messmer, E. Minchell and H.M.R.R.). At first these were taken for early specimens of *T. ixioides* Swz., but examination showed the columns in agreement with descriptions of *T. media*. The flowers, intermediate in size between those depicted by Fitzgerald and the larger Victorian form, were deeper in colour than those of *T. ixioides*, which was plentiful in the same locality two or three weeks later.

71. *Diuris maculata* Sm.—Neath Public School, August, 1931. This is the only specimen I have seen in the Hunter River district of this species, which is so abundant in other localities north and south. It was found by a schoolboy near Neath Colliery, and is quite typical.

72. *Prasophyllum elatum* R.Br.—Near Kurri Kurri and Pelaw Main, September, 1931. Fairly typical, up to 2 ft. 6 in. in height. One plant bore distinctly yellow flowers.

73. *Prasophyllum brevilabre* Hook.—Near Hebburn No. 1 Colliery dam, Weston, August, 1931 (Mrs. C. A. Messmer, E. Minchell and H.M.R.R.). Quite plentiful in this locality, but not seen elsewhere. Very variable in size.

74. *Pterostylis rufa* R.Br.—I have on several occasions called attention to the need for careful revision of this group in the genus *Pterostylis*, commonly called the "rufous" or "ruddy" Greenhoods. Published descriptions do not always agree; and there is undoubtedly discrepancy between the forms known in New South Wales as *P. rufa* and *P. Mitchellii*, and those recognized by these names in Victoria. *P. pusilla* var. *prominens*, a form described by me in These PROCEEDINGS, 1931, p. 136, is probably sometimes taken for *P. rufa*. While it is certainly not

that species, I have made it clear (*loc. cit.*) that I am not satisfied with its inclusion in *P. pusilla*. I have only once seen a rufous Greenhood with the curious globular hairy structure shown on the under-side of the labellum in Fitzgerald's *P. rufa*, and that particular plant was sent to me (in bud) as a Victorian *P. pusilla*. It is possible that—as was the case with *Corysanthes dilatata* until a few years ago—there is an unrecognized species causing confusion in the group. The *P. rufa* recorded here was found by me on the hill behind Neath Colliery in September, 1931, in association with *P. mutica* and *P. pusilla* var. *prominens*. Mr. E. Minchell and I searched diligently for further specimens in vain. The plant agrees with specimens from other localities in New South Wales, except for the unusual brilliance of the colouring—the flower is almost scarlet. It differs from *P. pusilla* var. *prominens* in the following respects: The flowers are quite erect on relatively short pedicels with much longer subtending bracts. The whole flower is broader, the lateral sepals are much so; and all sepals have longer caudae. The incidence of the very long white cilia on the labellum-margins is different; the labellum is very deep red from base to tip, the latter being neither bifid nor emarginate.

CORYSANTHES UNDULATA Cunn.

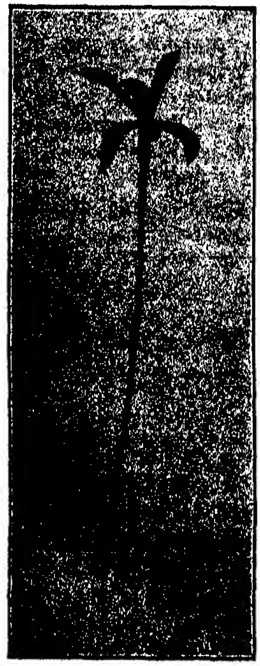
Russell Island, Moreton Bay, Queensland, June-July, 1931, Mrs. H. Curtis (new record for Queensland). Since the re-discovery of this long-lost little orchid at Bullahdelah in 1924 (see These PROCEEDINGS, liii, Part 2, 1928, p. 88, and references given there), it has not been recorded elsewhere until 1931. Mrs. Curtis sent me two living specimens in June, followed by more in July. They were identical in all respects with the Bullahdelah plants. It is a pity Cunningham's locality is not known. The occurrence of a species with the habits of this *Corysanthes* in such widely-separated localities as Bullahdelah and Moreton Bay suggests that it is probably not as rare as was supposed. At Bullahdelah I do not think it is ever in flower so late as July: May–June is the period. This leads me to remark that for some years I have had Queensland plants of *Dendrobium falcorostrum*, *D. aemulum*, and *D. teretifolium*. Every year they come into flower just as the New South Wales forms of these species are going off. I had supposed this to be due to the requirement of a temperature equivalent to that of their northern home. But if *Corysanthes undulata* flowers in Queensland some weeks later than it does more than 300 miles further south, some other cause is apparently to be sought.

CALADENIA ANGUSTATA Lindl.

Guyra district, New England, October, 1929, and 1930, Rev. E. Norman McKie (new record for N.S.W.). So far as I can ascertain, this species is not previously on record for this State, and its occurrence on the highlands of New England is interesting. It has hitherto been regarded as confined to the southern States, and in Victoria was for long confused with *C. testacea* R.Br., a very distinct species. Mr. McKie first sent specimens to me in 1929, but they suffered in transit, and I included them tentatively in *C. dimorpha* Fitzg. In 1930 I received specimens in excellent condition. I was inclined to regard the orchid as a large form of Fitzgerald's *C. cucullata*, but Mr. W. H. Nicholls determined it as *C. angustata*, and after exhaustive comparisons with my Victorian and Tasmanian specimens, I fully concur. It possesses a sweet musky odour akin to that of *Caladenia carnea* var. *gigantea*.

CALADENIA TESTACEA R.Br.

Teratological specimens are always of interest, and it is remarkable how often we find in them the labellum "reverting to type", i.e., returning to its original form as a third petal. In September, 1931, in company with Mr. E. Minchell of Weston, I found amongst a colony of *C. testacea* one specimen which, had it not been for its associates, I should have found difficult to place in any known species. The stem and leaf were those of *C. testacea*, but there the resemblance ended. The solitary flower was half as large again, and, except for purple specks all over the column, was wholly dull-green. The dorsal sepal, instead of forming a hood over the column, was reflexed backward like the other two. The paired petals were very convex: the labellum was a perfect petal, concave, horizontal, and devoid of any trace of calli. At one side of the usual anther at the top of the column was a second smaller anther.



Text-fig. 1.—Teratological specimen of *Caladenia testacea* from Weston.

DENDROBIUM TERETIFOLIUM R.Br. var. FAIRFAXII Fitzg. and v. M.

This variety of *D. teretifolium* (as I regard it) is itself exceedingly variable: so much so that it would be most difficult to attempt definitions of many of the forms. One sent in 1930 by the Rev. E. Norman McKie from the Guyra district, however, is very distinct and seems worthy of mention. Mr. McKie sent me a plant after the flowering season and, though he stated that it was growing on a tree, it appeared to me very like the rock-loving *D. striolatum*, the leaves being very short, curved, and slightly fluted. It flowered in September, 1931, and the flowers, though very small, conform in all other respects to the type of *Fairfaxii*. It may perhaps be a natural hybrid.

THE STRATIGRAPHICAL AND STRUCTURAL GEOLOGY OF THE DEVONIAN ROCKS OF THE SOUTH COAST OF NEW SOUTH WALES.

By IDA A. BROWN, B.Sc., Linnean Macleay Fellow of the Society in Geology.

(Plates xxx-xxxiv; seven Text-figures.)

[Read 25th November, 1931.]

INTRODUCTION AND GENERAL GEOLOGY.

A brief general account of several occurrences of Devonian rocks on the far South Coast of New South Wales has been given in a paper by the writer (1930), in which most of the known earlier literature on the subject is recorded.

The present paper describes in more detail the stratigraphical and structural relationships of the Devonian system as represented on the far South Coast of New South Wales, and suggests certain correlations with occurrences of similar age in other parts of south-eastern Australia.

Recent field work has shown that there is a much more extensive development of Devonian rocks in this region than was supposed formerly, when geological examination had been confined to the section along the main coast road or Prince's Highway, which runs over pre-Devonian sediments and granitic rocks for the greater part of two hundred miles; the country to the west of the road is not easily accessible.

It is now known that a belt of Devonian rocks runs from the coast south of Eden through Wolumla, Yourie, Nerrigundah and thence northwards across the Deua River, through the Clyde Mountain and on towards Yalwal. This general trend of Devonian rocks is suggested in the writer's previous paper (1930, p. 154), and is shown more clearly on the map accompanying the present paper.

It has not been found practicable to trace the beds continuously in the field owing to the mountainous and inaccessible nature of the country. The sequence has been examined in some detail in the Eden district, where the rocks have suffered least disturbance by post-Devonian earth movements; the knowledge thus obtained provided a key to the interpretation of various sections examined across the geosyncline to the north, as will be obvious from a consideration of the accompanying maps and sections.

It is proposed, therefore, to give an account of the geology of the Eden district, followed by descriptions of areas and sections to the north, and finally to suggest correlation with other areas in New South Wales and Victoria.

Previous Records.

Earlier descriptions of the geology of this area are mentioned in the writer's previous paper (1930). Of these, the most pertinent are the works of the late J. E. Carne, published in the Annual Reports of the Department of Mines and Agriculture, New South Wales, for 1896 and 1897. These include "Preliminary Notes on the Yowaka or Pambula Goldfield" (1896, pp. 107-122), "Report on Goldfind, Wolumla" (1896, p. 122), "Report on the Geology and Mineral Resources of the South-east Border of New South Wales between Cape Howe and the Head of the Murray River" (1897, pp. 151-160), and "Notes on the Geology and Auriferous Deposits of the Wolumla Goldfield" (1897, pp. 162-167).

These reports are essentially of an economic nature, but contain valuable information concerning the stratigraphy of the district. On account of more extended field-work the writer places an interpretation on many of the facts of field-occurrence, which differs from that of Mr. Carne, but this in no wise tends to diminish her appreciation of his careful observations.

The Jingera or Whipstick bismuth and molybdenite deposits occurring in granite, which is intrusive into Devonian rocks between Pambula and Wyndham, have been described by E. C. Andrews (1916*a*.).

In his Presidential Address to the Linnean Society of New South Wales, Assistant-Professor W. R. Browne (1929, p. xix) included a brief description of the Devonian igneous rocks of the district, based on Mr. Carne's reports and a re-examination of his rock-collections.

Other references will be given in the course of the paper.

The Geology of the Eden District.

The township of Eden is situated on the shores of Twofold Bay, on the south coast of New South Wales, about 350 miles by road from Sydney, and half-way between Sydney and Melbourne.

The coastal district between the Brogo River and the Victorian Border is drained by two large rivers and their tributaries, the Bega and the Towamba Rivers, which flow from the edge of the tableland eastwards to the Pacific Ocean, while the Genoa and Wallagaraugh Rivers rise in the southern part of the area and flow southwards across the border into Victoria. The smaller coastal rivers and creeks, such as Merrimbula, Pambula and Womboyne, flow into lakes, which form a characteristic feature of the coastal topography.

The physiography of the area is being considered in a paper in the course of preparation.

The geological nature of the underlying rocks has played an important part in the physiographical and economic development of the region under consideration. In general, sedimentary rocks outcrop from the coast inland for a distance of 6 to 12 miles, and the area to the west consists mainly of granite, which produces gently undulating topography. As a result, the district has good road communication with the Monaro Tableland lying to the west.

The principal roads are from Bega to Cooma over the Brown Mountain; the Tantawangalo road from Bega to Bombala through Candelo and Cathcart; the Wyndham and Towamba roads over Big Jack Mountain to Cathcart and Bombala; and the recently constructed Mount Darragh road from Wyndham to Cathcart. In addition, the maturely dissected granite country affords easy grades for numerous roads through the districts of Pericoe, Towamba, Burragate, Wyndham,

Candelo, Wolumla, Kameruka, Bemboka, Numbugga, Bega and Brogo. The more rugged and barren country composed of sedimentary rocks offers less inducement for road-making.

The Devonian rocks of the Eden-Pambula district outcrop along the coast north and south of Twofold Bay, and have been described by W. B. Clarke (1860), E. F. Pittman (1880) and J. E. Carne (1896).

These rocks are bounded on the west by intrusive granite and unconformably overlie older Palaeozoic schists and slates. The latter outcrop between the western portion of Twofold Bay and the Victorian Border, and again between Bega and Tathra, this being the southern extension of the outcrop from the Clyde River along the coastal districts through Narooma and Bermagui.

It is the writer's intention to give a detailed account of the older Palaeozoic rocks of the coast on a future occasion; in this paper merely incidental references will be made to the pre-Devonian sediments.

The distribution of the Devonian and older rocks of the Eden district is indicated on the accompanying map, Plate xxxiii.

Three divisions of the Devonian system are represented in the Eden district, (*a*) a lower volcanic stage, consisting of acid igneous rocks; (*b*) a middle stage, containing chocolate shales, thin-bedded buff and red grits and sandstones with interbedded igneous rocks; and (*c*) an upper stage consisting chiefly of marine conglomerates, grits, sandstones and quartzites containing Upper Devonian fossils.

(*a*) *The Lower Volcanic Stage.*

Members of the volcanic stage outcrop on the Womboyne River and along its southern tributary, Watergums Creek, and form a belt about 250 yards in width running from Disaster Bay, into which the Womboyne flows, in a northerly direction to Munganno Point, on the southern side of Twofold Bay. This outcrop is bounded on the west by folded pre-Devonian sediments, but no clear vertical section of the junction has been observed on the south side of Twofold Bay.

On the northern side of the Bay this belt outcrops over the peninsula on which the Eden Lighthouse is situated, and along the cliffs for a short distance to the north. It then swings westward through the town of Eden, under the Prince's Highway, where it is obscured by Tertiary drift formation, and continues to the south of the Nethercote road through rough country to the west; its extension beyond this has not been determined.

Similar rock outcrops at Bournda Head and its adjacent "tied island", about five miles north of Merrimbula; and 9 miles east of Bega, at Tathra and on the coast to the south, similar formations occur.

The rocks under consideration include the "quartz felsite or porphyry . . . . best studied at Eden", as described by Mr. Carne (1896, p. 110), who considered that these "igneous rocks are intrusive into the older sedimentary series (Silurian?) and partly so into the Upper Series (Devonian?), for undoubtedly the former are overlaid in parts by the latter."

The present writer is of the opinion that the igneous rocks are not intrusive into the Devonian beds, but occur below Upper Devonian sediments exposed in this area, and that they represent terrestrial flows of acid lava over the eroded surface of folded older Palaeozoic sediments.

The igneous rocks outcrop always between the older, highly folded series with meridional strike and the more gently folded Devonian beds. Frequently

some type of fluxion structure is developed which dips at an angle more or less conformably with that of the adjacent Devonian sediments, and sometimes columnar structure, platy-parting and jointing, probably parallel to the cooling surface, indicate a similar direction and amount of dip; these rocks will be referred to as rhyolites.

The actual junction of the older Palaeozoic sediments and the rhyolite is exposed in several cliff-sections close to the town of Eden, and also on the northern face of cliffs, north-west of the village of Tathra. The best exposure is at the base of the cliffs immediately west of the Eden Lighthouse, where columnar rhyolite dipping at 30 degrees to the east rests on the upturned and denuded edges of folded, older Palaeozoic rocks. Similar relations are apparent at Yallumgo Cove, Mirare Point and at Tathra (Plate xxx, figures 1 and 2).

On the south side of Twofold Bay the direction of banding in the rhyolite is approximately N.40°W., and the dip of this is E.40°N. at 45°. The overlying red shales and grits along the coast near here dip E.30°N. at 35° to 40°. Beach sand obscures the base of the rhyolite on the south side of Twofold Bay.

In the neighbourhood of Eden township and at Munganno Point measurements of the rhyolites indicate a thickness of between 450 and 500 feet.

It is highly improbable that only one flow occurs, for there are lithological variations and different types of structure on various horizons. Near the base of the series a very extraordinary type of spherulitic structure is developed, in which the spherulites range from an inch up to 14 or 15 inches in diameter (Plate xxxii, fig. 1). This phase is well exposed on Mr. J. R. Logan's property, "Edrom", on the south side of Twofold Bay, and has been recorded from near Eden by Mr. Carne (1896, p. 111). Columnar structure is well developed through the main portion of the series, particularly in the cliffs near the Eden Light (Plate xxx, figs. 1, 3), and on both sides of Yallumgo Cove. Sometimes the rock is amygdaloidal, and the vesicles may contain amethystine quartz, as in the cliffs below the Roman Catholic Convent; or crystallized haematite, popularly thought to be molybdenite. Platy-parting occurs at the east of "Edrom", at Eden and at Tathra.

The petrological characters of the rocks are considered later.

(b) *The Middle Stage.*

Rocks of the middle stage overlie the rhyolites and outcrop at the mouth of the Womboyne River; along the coast from Disaster Bay to Munganno Point, Twofold Bay; and extend along the coast from Eden to Tura Head, north-east of Merrimbula. They may be traced inland from Eden through the Nethercote district, across the Pambula-Wyndham road on towards Wolumla.

The relation to the underlying rocks is best exposed on the south side of Twofold Bay, on the property of Mr. Logan, where conglomerates and other shallow-water beds are deposited over the eroded surface of the rhyolite (Plate xxxi, fig. 1).

A large boulder of the conglomerate on the beach close to the junction contains fragments of the rhyolite and a large spherulite, thus confirming the previous observation of the post-rhyolitic age of the conglomerate and the overlying beds which are conformable with it.

The erosional break and the slight differences in dip which have been recorded thus point to a disconformity between the two series, probably indicating vertical movement and a change from terrestrial to sub-aqueous conditions.

On the northern side of the Bay, the junction of the rhyolite and the overlying series occurs in the cliff sections near the end of Chandos Street, Eden, slightly to the north of the R.C. Convent grounds. Here the nature of the contact is not so obvious as at "Edrom". It was probably some such section as this which led Mr. Carne to believe that the "porphyry" was intrusive into the adjacent sediments. A photograph of this cliff section appears in Plate xxxi, fig. 2. The rhyolite is on the left-hand side and its junction with sediments is almost vertical in the centre of the photograph: on the rock-platform in the foreground the gently-dipping conglomerate and shaly beds are seen to overlie an eroded surface of the rhyolite, a repetition of the condition at "Edrom". There is no trace of contact metamorphism of the sediments against the rhyolite, and the possibility of faulting is discounted by the relations of the two rocks on the adjacent rock-platform. The steep junction of the two series is explained best as being due to the deposition of sediments on a slowly subsiding floor against an old cliff headland of rhyolite. The rhyolite is in contact with red beds again in a small valley (Portion 136, Parish of Bimmil) near the road from Eden to Nethercote, but their relations are obscured by cultivation. The rhyolite of Bournda is separated from the red beds by stretches of Tertiary and recent sands.

The rocks of the middle stage consist largely of the "clay-slates" of W. B. Clarke (1860), which have been described by J. E. Carne (1896, p. 110). These form conspicuous cliffs along most of the coast from Disaster Bay to the north of Merrimbula, where they are interbedded with thin bands of red, purple and buff-coloured sandstones and grits, some of which may be tuffaceous.

In the Nethercote district and to the north the sediments are interbedded with rhyolites, felsites and amygdaloidal basalts.

Typical sections of this stage are exposed east of the rhyolite at Munganno Point, at the south end of the Ocean beach at Eden, at North Head of Twofold Bay, at Lennard's Island, Pambula Heads and Merrimbula Head, and along most of the roads and tracks west of the Prince's Highway.

East of the rhyolite at Munganno Point the rocks consist of a series of alternating red shales and yellow grits, whose dip is somewhat variable, the average being in a direction E.30°N. at 35° to 40°.

North of the rhyolite at Eden a similar series of interbedded red clay-slates, quartz-grits, purple, grey and buff sandstones and thin green shales dip N.30°W. at 12°, the strike swinging round in approximate conformity with that of the underlying rhyolite. On account of local folding the beds a few hundred yards to the north dip N.40°E. at 12°. From the cliff section north-east of the Convent, Miss G. Joplin, B.Sc., collected a specimen of red shale containing fragmental plant remains, some of whose pinnules show well-preserved venation, which Dr. A. B. Walkom considers are possibly fragments of *Cordaites* of Upper Devonian age.

In the Museum of the Department of Geology, the University of Sydney, are specimens of *Protolepidodendron*, similar to those described by Dr. Walkom (1928) from Yalwal. These were collected by Dr. W. G. Woolnough from the east of Eden (see These PROCEEDINGS, liii, 1928 (1929), p. xl).

There is a fair amount of local folding throughout the middle stage, which may be seen in most of the sections along the coast. The directions and amounts of dip are indicated on Plate xxxiii.

The shallow-water origin of the beds, suggested by the presence of *Cordaites*, is confirmed by the preservation of sun-cracks and fine ripple-marks in the red

shaly beds and overlying sandstones in the rock-platform north of Merrimbula Head.

This stage of the Upper Devonian is no doubt analogous to that of the Nungatta and Yambulla Ranges, near the head of the Genoa River. Of these beds, J. E. Carne (1897) writes: "This formation consists of alternations of quartz-pebble conglomerates, grits, sandstones and clay shales." "In the clay shales, which are frequently strikingly red-coloured and ferruginous, abundant obscure impressions of plant remains occur both at Yambula Peak and further west on the Genoa River. In the greenish-grey arenaceous shales and finely laminated sandstones the impressions are better preserved. Amongst a number of specimens collected at the above localities Mr. Dun was able to identify the following forms: *Archaeopteris Howitti* McCoy, *Cordaites australis* McCoy, *Sphenopteris Carnei*, sp. nov., *Pecopteris* (?) *obscura*, sp. nov."

An association of similar plant remains in the Upper Devonian beds of the Perry Basin of South-eastern Maine has been described and figured by D. White (1905, p. 68), who considers that Mr. Dun's description (1897) of " "*Pecopteris* (?) *obscura*" from Genoa River leaves little room for doubt as to the identity of the latter with *Barinophyton*".

Interbedded with the sediments of the middle stage are a number of volcanic flows, which outcrop to the west of the Prince's Highway. These have not all been mapped in detail, but their approximate positions are indicated on Plate xxxiii. The detailed petrological characters are described later.

The rhyolites outcrop in the Nethercote district, along the Yowaka River and its tributaries, through the Mt. Gahan ridge, and in the neighbourhood of Lochiel. They show pronounced banding and spherulitic structures, and are usually of a cream, pink or purple colour.

The basalts are generally amygdaloidal, although the stratigraphically lowest horizon is a fairly compact rock. They are characterized by an abundance of epidote, and in places veins of fibrous asbestos and quartz occur. These characters are generally sufficient to distinguish them from the limited outcrops of Tertiary basalt in the district.

The variety of rock-types present in the middle stage, the local folding of beds, and the poor exposures of consecutive sections render the determination of the thickness of this stage somewhat difficult. Measurements indicate a thickness of between 1,500 and 2,000 feet.

(c) *The Upper Stage.*

The red beds of the Middle Stage are succeeded by an Upper Stage of massive conglomerates, sandstones and quartzites, with thin bands of red shales, which contain no volcanic rocks so far as the writer is aware. As a rule these beds are nearly horizontal or only slightly dipping. These differences in the amount of folding and the marked lithological change from fine-grained, soft red shales to coarse massive conglomerate indicate a break in the conditions of deposition amounting to a disconformity or perhaps even unconformity.

Unfortunately no clear vertical exposure of the junction is known to the writer, for the cliffs along the coast are carved out of the middle stage of red beds. Perhaps the relations may be traced by detailed work near the turn-off to Nethercote on the Prince's Highway at the Yowaka-Saltwater Bridge, or in the cliff sections on Broadwater Lagoon, but these are somewhat inaccessible.

Near the head of Bald Hills Creek, north-east of Pambula Trigonometrical Station, there is an extensive outcrop of typical amygdaloidal basalt, which is overlain by dipping red shales at a turn of the creek. Above the red shales are almost level-bedded massive purple conglomerates, more or less silicified, and strongly jointed; the vertical master-joints cut through the included pebbles and give the appearance of artificial "marble", thus probably accounting for the popular name of the locality. Somewhat similar relations occur along the Pambula River near the "Six Mile", on the road from Pambula to Wyndham, where the basalt outcrops in the bed of the river, and the overlying massive conglomerates cap the hills to the east.

It is considered that the central portion of the outcrop of the Devonian rocks between Eden and Wolumla, including the sandstones and quartzites of Bellbird Creek, the Bimmel Mountain, and the higher parts of the area between Pambula, Merrimbula and Wolumla, consist chiefly of rocks of the Upper Stage. At the southern end of this outcrop there is evidence of overlap of the basal conglomerates of the Upper Stage on the lower stages, west of the Prince's Highway, and a mile south-west of Eden.

Further evidence of the more extensive development of the Upper Stage is afforded by outliers of this stage resting directly and unconformably on the pre-Devonian sediments along a ridge followed by the Towamba road, north of the Nullica River, and also on the top of Mount Imlay (Text-fig. 1, Section 4). The older Palaeozoic series outcrops on Mount Imlay up to about 1,800 feet above sea level, above which are almost horizontal red beds, followed at the 2,100 foot level by conglomerates, grits and sandstones, with occasional bands of red shales. The Trigonometrical Station at the top (2,913 feet) is situated on a band of red shale. No igneous material has been observed by the writer in this section, and it is considered that only the upper stage is represented here. The lithological differences in the rocks comprising the mountain are responsible for the varying resistance to erosion and the resultant angle of slope, which has produced a distinct shelf at the top of the older sediments.

The thickness of the Upper Stage is estimated at about 1,200 feet, but, as the upper surface is eroded, it may have been originally much greater.

Fossils have been found in only two localities, as recorded previously by the writer (1930, p. 153). From Bellbird Creek, three miles north of Eden, the following forms have been recorded (J. E. Carne, 1897; I. A. Brown, 1930): *Rhynchonella pleurodon*, *R.* (?) *cuboides*, *Atrypa* sp. (?) *reticularis*, *Polyzoa*, *Phthonia*, *Aviculopecten* (?). W. N. Benson (1922) records *Rhynchonella primipilaris* from Wolumla Creek. The quartzites of Bellbird Creek contain worm tracks and well-preserved ripple-marks as additional evidence of their shallow-water origin.

Other Occurrences of Devonian Rocks on the South Coast.

Descriptions of other occurrences of Devonian rocks have been given by the writer (1930) and others, but, for the sake of clearness, these accounts are summarized in the following pages and some additional details are recorded.

Diagrammatic sections across the areas mentioned are given in Text-figures 1 and 2.

(a) *The Quaama-Cobargo District.*

The village of Quaama is situated on the Prince's Highway between Bega and Cobargo, on the granitic batholith extending from Victoria to the north of Cobargo.

About three miles east of Quaama, a tributary of the Murrah or Dry River, Pipeclay Creek, works its way along the junction of the granite and the intruded rocks. On the eastern side of Pipeclay Creek and south of the Old Bermagui Road are gently dipping sandstones and quartzites containing typical Upper Devonian fossils, determined by Mr. W. S. Dun to be *Spirifera disjuncta*, *Rhynchonella pleurodon*, *Pterinea* and *Pteronites*. The discovery of Devonian forms in this district was due in the first place to Dr. A. A. Pain, as previously recorded by the writer (1930), who has subsequently collected these fossils from other localities in the district.

There is considerable variation in the dip of these beds, no doubt on account of their proximity to the intrusive granite batholith. In the upper parts of Pipeclay Creek the rocks are almost horizontal, and consist of bluish and purple sandstones and quartzites remarkably similar to those at Bellbird Creek, north of Eden. Strong jointing is developed in a direction N.10°W.

Underlying the Upper Devonian with a strong unconformity are thin-bedded conglomerates, slates and black cherts, in which graptolites were discovered in a hill overlooking the swimming pool at Pipeclay Creek; these Ordovician rocks dip steeply to the south-west.

North of this area, towards Cobargo, the granite is in contact with Devonian sediments, but on the main road six miles east of Cobargo it intrudes steeply-dipping, sandy slates and black cherts, whose direction of strike is almost meridional. Contact altered quartzites, possibly of Devonian age, occur in the neighbourhood of Sam's Creek, near the road from Cobargo to Dignam's Creek, and similar rocks outcrop to the west near the road from Cobargo to Wandellow. Between these localities, north-west of the Narira Trigonometrical Station, Ordovician rocks outcrop, from which C. F. Laseron obtained *Diplograptus foliaceus* Murchison, *Climacograptus* sp. and *Dicellograptus* sp. (W. R. Browne, 1914, p. 194).

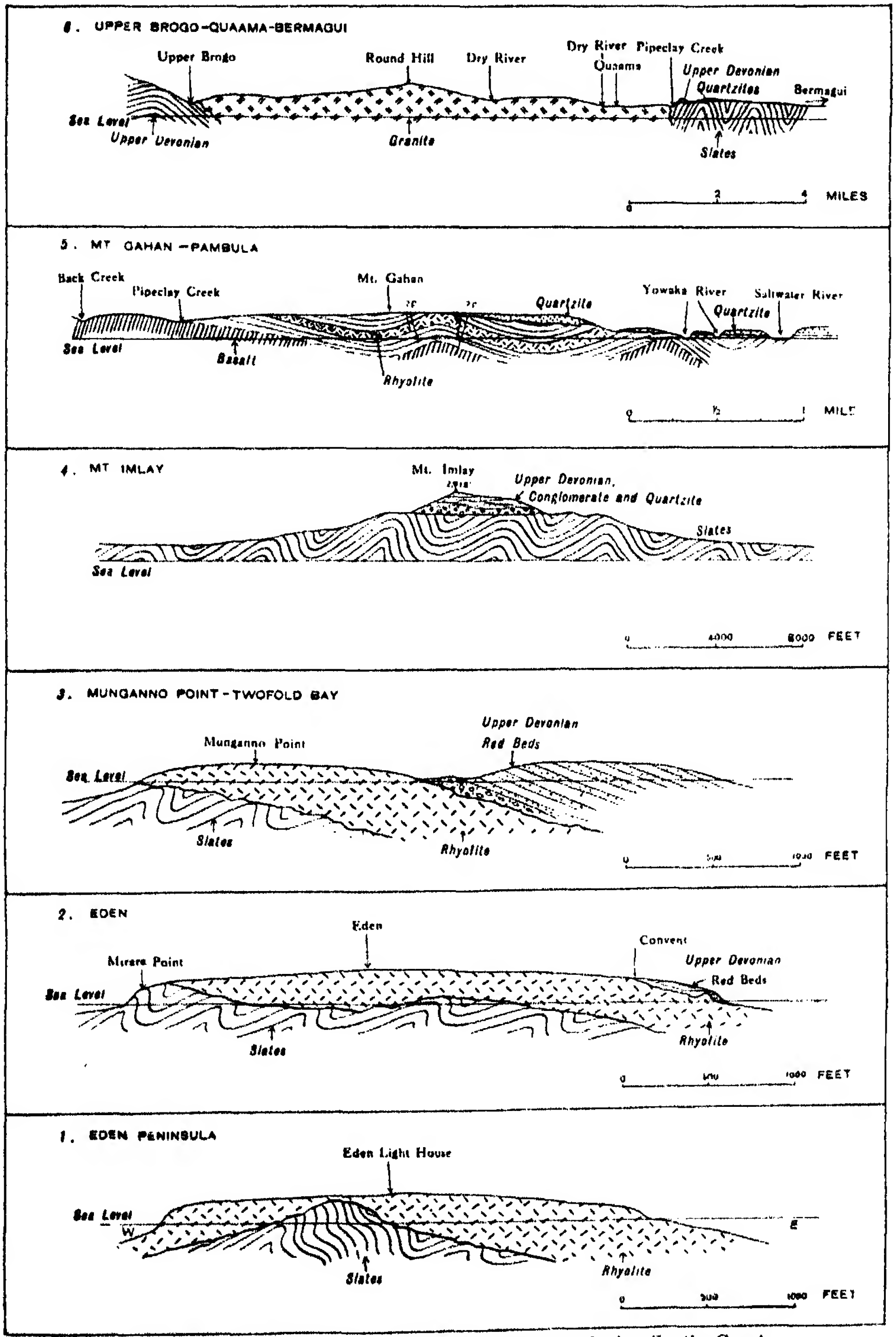
Granitic rocks extend a considerable distance to the west of Quaama, and near the head of the Brogo River (Portion 10, Parish of Mookerah, County of Auckland) they are in contact with purple sandstones and quartzites with interbedded red shales, similar to the Devonian beds of the Eden district. These sediments dip E.35°N. at 45°, and the intrusive granite appears to have worked its way along the bedding planes of the invaded sediments; there is clear evidence that the granite is later than Upper Devonian.

Rough inaccessible country separates the outcrop of this contact from that exposed at Yourie, some 10 miles north-west of Cobargo, where the granite again intrudes sediments having the lithological characters of the Upper Devonian.

A diagrammatic section from Upper Brogo to the east of Quaama is given in Text-figure 1, section 6.

(*b*) *Nerrigundah to Eurobodalla.*

Folded pre-Devonian rocks extend from the coast in the neighbourhood of Narooma, to Bodalla and Eurobodalla, on the Tuross River. West of Tuross Bridge at Eurobodalla are typical Upper Devonian sediments, purple quartzites and interbedded chocolate shales, which extend as far as Nerrigundah and form a ridge about 700 feet in height. These sediments are folded in a meridional direction, the dips amounting to about 25 degrees. West of Nerrigundah outliers of Devonian sediments form cappings to hills, which consist chiefly of the highly



Text-fig. 1.—Diagrammatic geological sections of the South Coast.

folded pre-Devonian series. Gold-bearing reefs occur in the older series, and these have been described by L. F. Harper (1923).

The Devonian beds are about 1,000 feet in thickness, and are lithologically similar to those of the upper stage at Eden. No interbedded igneous rocks are known to occur here (Text-fig. 2, section 1).

(c) *Wamban Creek.*

Quartz-porphyry or rhyolite occurs about seven miles south-west of Moruya, south of Wamban Creek, the general direction of strike being slightly west of north. This outcrop is possibly a continuation of the rhyolite occurring at the junction of Burra Creek and Deua River. About a quarter of a mile west of the porphyry is a conglomerate ridge bearing N.40°W. and S.40°E., which runs through the Little Sugarloaf and the Wamban Sugarloaf, and continues towards the Bendithera Track to the north. These rocks are lithologically similar to the Upper Devonian of the coast.

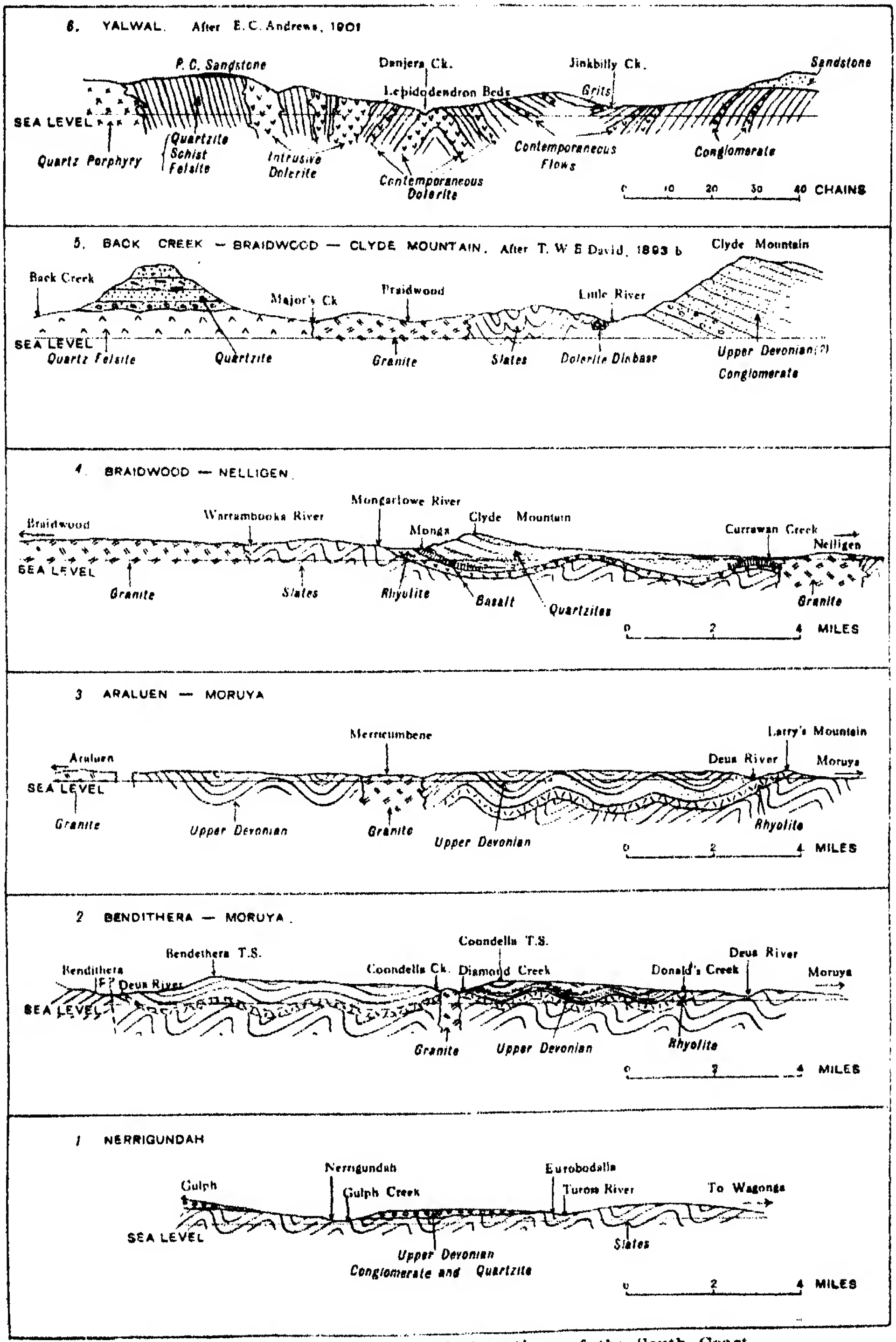
(d) *Section along the Bendithera Track, West of Moruya.*

The section from Moruya to Bendithera has been described in detail by the writer (1930). Devonian rocks outcrop between the junction of Burra Creek and the Deua River and Bendithera near the head of the Deua River. These beds overlie the rhyolite outcropping along the Araluen Road south of Larry's Crossing; they have been cut through by Diamond Creek, a southern tributary of Burra Creek, and possibly by the Upper Deua River at Bendithera, so that the basal (?) rhyolite is exposed.

The series is more strongly folded along this section than in the southern areas, the general trend of the fold axes being in a north-north-westerly direction. The rocks comprise conglomerates, quartzites and purple clay-slates; a thin bed of quartzite crowded with casts of *Spirifera disjuncta* outcrops south of Coondella Trigonometrical Station at an elevation of nearly 1,900 feet above sea level, and thus indicates an Upper Devonian age for the series (Text-fig. 2, section 2).

(e) *Deua River Section.*

The section along the Deua River was described by the writer in 1930, and its re-examination since the study of the Eden district confirms the previous suggestion that the sediments are of Upper Devonian age. It is now known, however, that the "porphyry" outcropping to the west of Moruya for several miles along the Deua River below Larry's Crossing is not intrusive, but takes the form of a series of flows over the surface of the older Palaeozoic schists which outcrop to the east. The western portion of the outcrop shows very distinct rhyolitic banding, especially in the slightly weathered rock, and the dip of the banding is in a westerly direction at 35 degrees, that is, approximately conformable with that of the overlying Upper Devonian sediments. The rhyolite is brecciated in places, a feature which may be due to movement of the lava under a partially consolidated crust, and is associated with tuffs on some horizons. The rhyolitic nature of the occurrence is confirmed in the field by its extension northwards, where it forms the upper portion of the range through the Wandera Mountain, west of the Buckemboura district. The field-relations therefore suggest its correlation with the Eden rhyolite and its lithological and chemical characters are strongly in favour of this supposition. The approximate thickness of the rhyolites and tuffs in this locality is about 700 to 800 feet. The lithological characters are described later, page 474.



Text-fig. 2.—Diagrammatic geological sections of the South Coast.

The overlying series of sediments has been described previously by the writer (1930). Lithologically the rocks bear very striking resemblances to the Upper Devonian rocks of the Eden district, and like them contain purple sandstones and quartzites with well-preserved ripple-marks as evidence of their shallow-water origin. A good example occurs near the 22 mile-peg from Moruya in beds that dip W.20°S. at 65° (Plate xxxi, fig. 3).

An important feature of this section is the high degree of folding of the sedimentary series as compared with that of the occurrences to the south. The direction of the fold-axes varies from north and south (magnetic) to N.20°W. and S.20°E., and the intensity of the folding increases as the granite batholith of the Araluen district is approached (Text-fig. 2, section 3).

(*f*) *Bateman's Bay to Braidwood via Monga.* Text-fig. 2, section 4.

The portion of the section from Bateman's Bay to the Clyde Mountain has been described previously by the writer (1930). West of the Clyde Mountain the road rises to a height of more than 2,500 feet above sea-level on the edge of the Main Divide, east of the village of Monga. It then runs in a northerly direction along the Mongarlowe River, a tributary of the Shoalhaven River, for six or seven miles before turning westwards to Braidwood. The granite of Araluen and Braidwood extends almost to the Mongarlowe River, where it is bounded by the older Palaeozoic series, consisting here of bluish-black slates dipping W.10° N. at 75°. A couple of miles to the south-east a hard bar of felsitic rhyolite, similar to that of Eden and the Lower Deua River, causes a waterfall in the Mongarlowe River. The flow structure in this rhyolite dips to the south-east.

At the village of Monga and along the river to the north, the rhyolite is overlain by a basaltic flow. A small quarry in the upper portion of the flow at Monga shows well-developed columnar structure; the rock is amygdaloidal, contains veins and amygdules of epidote, and is lithologically similar to the basalts of Nethercote and Pambula. The eroded upper surface of the basalt is exposed in the quarry and in the adjacent road-cutting, where it is overlain by about 10 feet thickness of red shales dipping south at 45 degrees, followed by interbedded purple quartzite and conglomerates containing rounded boulders of hardened red shales and purple quartzite, a typical Devonian sequence. Monga is about two miles west of the Clyde or Sugarloaf Mountain, where *Rhynchonella pleurodon* occurs in abundance in greenish-grey quartzite (T. W. E. David, 1893*a*; H. I. Jensen, 1908; W. S. Dun, 1930).

It is probably an extension of the basalt at Monga that has been described by H. I. Jensen (1908, pp. 57-58) as follows: "The basaltic mass which I examined in a valley near Sugarloaf Mountain is over half a mile wide and extends in a north and south direction for about ten miles. . . . The rock here termed basalt is a volcanic rock, in places quite vesicular and amygdaloidal." "The rock is certainly later than the Silurian schists and probably later than the Devonian, and may even be as late as the Tertiary, but its exact relations to the Devonian I have not yet worked out. The surrounding rocks are Devonian shales, quartzites and tuffs. They contain well preserved fossils, *Rhynchonella pleurodon*, *Spirifer disjuncta* and *Chonetes*."

This outcrop is indicated on the State geological map to the west of Budawong Mountain, and from its lithological character and field-associations there is little

doubt that it is a continuation of the Devonian basalt examined by the writer at Monga.

(*g*) *Major's Creek, near Braidwood.*

At Major's Creek, about ten miles to the west of Monga, Upper Devonian sediments rest on an eroded surface of quartz-felsite (Text-fig. 2, section 5); this occurrence was described by W. Anderson (1892), T. W. E. David (1893*a* and 1893*b*), and T. W. E. David and E. F. Pittman (1893). The latter authors write: "In July, 1892, Mr. T. P. Hammond, assistant to Mr. Geological Surveyor W. Anderson, discovered *Lepidodendron australe* in association with marine fossils, in rocks which are probably of Upper Devonian age on a hill overlooking Back Creek, about three miles from Major's Creek township. A number of other specimens of *L. australe* (some of them *in situ*) were subsequently discovered in this locality by Mr. W. Anderson and the authors. . . . The specimens are preserved as casts in ferruginous gritty sandstones, below which occur purple shales succeeded by marine grits and a basal conglomerate of quartz-felsite resting on an irregularly eroded surface of quartz-felsite."

Later (1893*b*) Professor David suggested the correlation of these Upper Devonian sediments with those of the Clyde Mountain and Mt. Lambie in New South Wales and with the Avon River sandstones and shales in Victoria. Of the underlying felsites he said: "The possibility suggests itself of this quartz-felsite being homotaxial with the Snowy River porphyries, which are probably of Lower Devonian age, according to A. W. Howitt and R. A. F. Murray."

(*h*) *Yalwal District.*

The Devonian rocks outcropping between Nelligen and Monga extend northwards and underlie the Permo-Carboniferous (Upper Marine) formation south of the Shoalhaven River. They are exposed by Ettrema and Yalwal Creeks, tributaries of the Shoalhaven, and have been described from Yalwal by E. C. Andrews (1901) as a series of folded sediments containing contemporaneous lavas (Text-fig. 2, section 6).

Mr. Andrews writes (p. 15): "The order of succession appears to be as follows: First a series of Devonian mudstones, sandstones and allied rocks were laid down.

"Intermittent periods of intense vulcanicity occurred at this period" during which immense rhyolite and basic flows were poured forth from various local centres.

"The higher members of the Devonian series consist of soft shales, grits and soft and hard tuffaceous material containing numerous *Lepidodendron* remains. With these are associated several sheets of very vesicular dolerite, numerous dolerite sills and smaller rhyolite flows."

No marine fossils have been found in the Yalwal series.

The rhyolites show conspicuous flow structure, and (p. 22) "a most interesting feature is the occurrence of large spherulites, varying in size from a pin's head to subspherical and ellipsoidal bodies two inches in diameter. The flow structure passes uninterruptedly through them. Concentric structure is plainly visible in some of the individual spherulites."

The dolerites are amygdaloidal, the amygdules containing "chloritic products, quartz, calcite and epidote" and the rock is traversed by "long strings of epidote and serpentine", a description which applies equally well to the basalts of Nethercote and Pambula, and with which they probably may be correlated.

It is interesting to note that (p. 22) "Copper . . . . has been found in one of the dolerite flows", an occurrence that is probably analogous to that described by H. I. Jensen (1908) from the basalt near Sugarloaf (Clyde) Mountain and Monga.

The *Lepidodendron* remains mentioned by Mr. Andrews have been described and identified by Dr. A. B. Walkom (1928) as *Protolepidodendron lineare*, n. sp., *P. Yalwalense*, n. sp., and *Lepidodendron* (?) *Clarkei*, n. sp. These plants are generally considered to be early forms, more primitive than the *Lepidodendron australe* of Major's Creek and Mt. Lambie.

To the north and west of Yalwal is a series of more arenaceous sediments (shown as "quartzites, and siliceous slates" on the map accompanying the Memoir of the Geological Survey, Geology, No. 7, by L. F. Harper (1915)) in which C. F. Laseron (1908, 1910) found Devonian marine fossils.

From the quartzites, sandstones and grits at the junction of Yalwal and Ettrema Creeks, Mr. W. S. Dun identified: *Allorisma* sp., *Sphenotus* sp., *Leptodomus* sp., *Pterinea* sp., and *Goniophora* sp., and from the Shoalhaven River, three miles west of Yalwal Creek: *Bellerophon* sp., *Euomphalus* ? sp., *Naticopsis* ? sp., *Mourlonea* ?, *Goniophora* ?, *Ctenodonta* sp., *Spirifera disjuncta*, and *Rhynchonella pleurodon*.

The relations between the Yalwal series and the Shoalhaven series of marine Devonian beds have not been observed, although C. F. Laseron (1908) gives some evidence in favour of the possibility that the marine beds overlie the Yalwal beds.

PETROLOGY OF THE VOLCANIC ROCKS.

Igneous rocks of probable Upper Devonian age on the South Coast may be grouped in three divisions: (1) Rhyolites occurring below Upper Devonian sediments; (2) rhyolites, rhyolite-breccias and felsites interbedded with Upper Devonian sediments; and (3) basaltic rocks partly intrusive into, and partly interbedded with Upper Devonian sediments.

(1). The first division comprises the lower volcanic stage of the Eden series, including the rhyolites of the Womboyne River, the rhyolite belt on both sides of Twofold Bay, the outcrops at Bournda Island, the coast near Tathra, Wandellow (?), the acid porphyritic rocks of the Lower Deua River, Diamond Creek (?), and the acid flows of the Mongarlowe River, north of Monga. Possibly the quartz-felsite of Major's Creek (T. W. E. David, 1893*b*, and W. Anderson, 1892) also belongs to this group.

The field occurrences have been described previously, where mention is made also of most of the macroscopic structures, such as columnar, nodular or spherulitic, and various types of fluidal structures in the rocks.

In the handspecimen the rocks vary in colour, texture and mineral constitution. The colour may be cream, light or dark grey or purple. The rocks are usually porphyritic; the phenocrysts are less than three millimetres in diameter, and are of quartz, or quartz and felspar; in some of the rocks of the Lower Deua River

the phenocrysts are very small and consist of orthoclase. The groundmass is lithoidal or felsitic.

Under the microscope the quartz phenocrysts show corrosion; the felspar is generally altered, but appears to be acid plagioclase as a rule; orthoclase has been noticed only in the Deua River rocks. The rhyolite from the quarry at "Edrom", Eden, shows pseudomorphs in chlorite and iron oxide apparently after a ferromagnesian mineral. The groundmass is devitrified, microcrystalline or hypohyaline. Frequently the fluidal fabric is indicated by streaks in the groundmass of varying crystallinity. Radiating spherulitic structure is present in some sections.

A section of one of the larger spherulites from Munganno Point shows concentrically arranged layers of flinty material, with slight radiating structure, through which the original flow-lines may sometimes be seen to pass. In the centre there is an amygdule of crystallized quartz, and the spherulite appears to be a secondary structure developed about the original geode at the expense of the rhyolite (Plate xxxii, fig. 2). The structure resembles that described in great detail by Cole (1886) and Parkinson (1898, 1901) as "pyromérides", and seems to be due to the replacement and growth of normal spherulitic structures by flinty material. On weathering, the surface of the outer layer exhibits an appearance similar to perlitic cracking in rhyolites.

Two analyses of rocks of this series have been made, and are given in Table I. The first is of the rhyolite from the quarry at "Edrom", Twofold Bay, which is typical of the rocks in this district; the second is of a banded rhyolite near the top of the rhyolite series outcropping along the Lower Deua River, west of Moruya.

The analyses quoted in Table I are very similar, being both those of normal potassic rhyolites, and as such show resemblances not only to those of Devonian age, but also to some described by H. C. Richards (1916) and H. C. Richards and W. H. Bryan (1924) of Permo-Carboniferous and even Tertiary age.

The excess of potash over soda is shown in the norm by the greater abundance of orthoclase than plagioclase, although this does not appear to be so in the mode. The felspar phenocrysts are usually plagioclase; anorthoclase is suspected in one rock (M. 960), and orthoclase occurs in some of the Deua River rocks. Apparently much of the potash occurs in the minerals of the groundmass.

The analyses are compared with those of three rocks from the Gippsland district of eastern Victoria, two being from the Wellington district and one from Mt. Tara Range, belonging to the Snowy River porphyry series.

The Mount Wellington rocks have been referred to by A. W. Howitt (1876–77), R. A. F. Murray (1877, pp. 44-57), E. W. Skeats (1909), E. O. Teale (1920), and others, and form part of a flow or series of flows between 1,000 and 2,000 feet in thickness at the base of sediments of probable Upper Devonian age. Thus they occupy a position analogous to that of the South Coast acid volcanic rocks. E. O. Teale (1920, p. 125) notes that "the porphyries and rhyolites of the Wellington Series form again a more acid series than those of the Snowy River". This is clearly seen by a comparison with the analysis in Column V of an acid porphyrite from Mt. Tara, in the Snowy River Series.

TABLE I.

	I	II	III	IV	V	VI	VII	VIII
SiO_2 ..	75·34	75·91	78·64	78·47	72·55	62·56	74·72	69·24
Al_2O_3 ..	11·89	11·89	9·85	10·68	11·74	16·60	13·05	12·88
Fe_2O_3 ..	1·54	1·58	0·54	0·18	2·54	1·02	0·52	0·20
FeO ..	1·60	0·96	2·00	2·23	0·46	5·98	1·42	4·05
MgO ..	0·28	0·47	0·10	tr.	0·68	2·71	0·41	2·21
CaO ..	0·16	0·26	0·80	0·66	1·85	4·30	0·66	3·10
Na_2O ..	2·06	2·23	2·03	3·29	3·46	2·98	3·62	2·94
K_2O ..	3·82	5·59	5·16	4·15	4·41	2·57	4·31	3·66
H_2O+ ..	1·18	0·58	0·40	0·2	0·41	0·68	0·61	0·80
H_2O- ..	0·16	0·09	0·14	0·09	0·06	0·18	0·13	0·06
CO_2 ..	1·60				1·80		0·08	
TiO_2 ..	0·31	0·28	0·67	0·59	0·175	1·10	0·16	0·04
P_2O_5 ..			tr.	tr.	0·14	0·17	0·38	abs.
MnO ..	tr.	tr.				tr.		0·06
Other Con.								0·82
	100·04	99·84	100·33	100·54	100·27	100·85	100·07	100·06

TABLE OF NORMS.

	I	II	III	IV	V	VI	VII
Quartz		40·68	44·70	40·98		18·48	35·58
Orthoclase		33·36	30·58	24·46		15·57	25·58
Albite		18·86	16·77	27·77		25·15	30·39
Anorthite		1·39	2·78	2·22		20·57	0·56
Corundum		1·63	—	....		1·83	2·24
Diopside		—	0·96	0·99		—	—
Hypersthene		0·10	2·05	2·51		15·12	2·85
Magnetite		2·32	0·70	0·23		1·89	0·70
Ilmenite		0·61	1·22	1·06		2·13	0·30
Apatite						0·34	0·93
Class		I	I	I		II	I
Order		3	3	3"		4	3
Rang		1	1	1"		3	1
Subrang		(2)3	2	3		(3)4	3
Magmatic Name.		Alaskose	Magdeburgose	Alaskose		Tonalose	Alaskose

I.—Rhyolite, Quarry, east of "Edrom", East Boyd, Twofold Bay. Anal. I.A.B.
II.—Rhyolite, Deua River, road to Araluen, 11 miles from Moruya. Anal. I.A.B.
III.—Banded Rhyolite, Southern Plateau of Wellington, Victoria. Anal. E. O. Thiele. *Proc. Roy. Soc. Vict.*, xxi, Part i, 1908, p. 266. Norm from Washington's Tables, p. 59.
IV.—Quartz-porphyry, southern shore of Lake Karng, Wellington district, Victoria. Anal. G. Ampt. *Proc. Roy. Soc. Vict.*, xxi, Part i, 1908, p. 266. Norm in Washington's Tables, p. 71.

V.—Quartz-porphyrite, No. 100, Mt. Tara Ranges, Snowy River Porphyry Series. Anal. E. O. Teale. *Proc. Roy. Soc. Vict.*, xxxii, Part ii, 1920, p. 125.

VI.—Dacite, Willimigongong Creek, near "Cheniston", Upper Macedon. Anal. Lewis and Hall. *Bull. Geol. Surv. Vict.*, No. 24, 1912, p. 17. Norm from Washington's Tables, p. 401.

VII.—Rhyolite, Blue Hills, Taggerty. Anal. E. S. Hills. *Proc. Roy. Soc. Vict.*, xli, Part ii, 1929, p. 189.

VIII.—Hypersthene-bearing quartz-porphyry, Burrenjuck, near Yass. Anal. J. C. H. Mingaye. *Ann. Rept. Mines Dept. N.S.W.*, 1907, p. 185.

These analyses may also be compared with that of a rhyolite from the Blue Hills, Taggerty, which also occurs near the base of Upper Devonian sediments, and has been described by E. S. Hills (1929).

The table of norms shows the similarity of the Deua River, Lake Karng and Taggerty rocks even more distinctly, and they all belong to the same subrang according to the C.I.P.W. classification.

On account of slight carbonation, the norms of the Eden rhyolite (Column I) and the quartz-porphyry from Mt. Tara Ranges (Column V) were not calculated.

The dacites of Mt. Macedon, a typical analysis of which is quoted in column VI, are described by E. W. Skeats (1909) and E. W. Skeats and H. S. Summers (1912) as probably equivalent to the Snowy River porphyries and of Lower Devonian age; the later work of E. S. Hills (1929) suggests that the Macedon dacites may be Upper Devonian. The rock is more basic than the South Coast series.

Similarly the porphyrite from Burrenjuck, whose analysis is quoted in Column VIII, shows resemblance to the South Coast rocks: it occurs between intrusive granite and the Middle Devonian rocks of the Murrumbidgee district, described by L. F. Harper (1909*a*).

(2). The second division consists of rhyolites, rhyolite breccias and felsitic rocks interbedded with sedimentary rocks of Upper Devonian age. The best exposures of these rocks in the Eden district occur to the west of Eden, through the Nethercote district and northwards to the Mt. Gahan Ridge and the Pambula to Wyndham road; the outcrops are indicated on Plate xxxiii. Similar rhyolites interbedded with Upper Devonian sediments have been described from Yalwal (E. C. Andrews, 1901).

The rhyolites and felsites of this stage differ from most of the rocks of the lower stage in having few or no phenocrysts. The rocks show little variation; they are very fine-grained and frequently show well-developed banding due to flow structure. Macroscopic and microscopic spherulitic structures also occur. Specimens of acid rocks belonging to this and the lower stage have been collected by the writer from about seventy different localities, and the Mining Museum, George Street North, Sydney, contains specimens from the Mt. Gahan Goldfield.

Under the microscope the rocks are seen to be devitrified, and the fluidal fabric is shown by variations in the grainsize of the different bands. The phenocrysts, which are seldom present, consist of either the acid plagioclase, oligoclase (M.960, M.859), or orthoclase, both of which are decomposed, and rarely quartz. The groundmass is very finely crystalline, frequently showing spherulitic structure (M.960, M.775). A section of an altered rhyolite from Mt. Gahan (M.749) shows well-developed perlitic fracture in ordinary light.

No chemical analyses of these rocks have been made; many of them look very similar to the rhyolite from the Deua River, whose analysis is given in Table I.

(3). Amygdaloidal basalts form the third group of Devonian igneous rocks. The chief outcrops occur west of Eden and in the Nethercote district, where at least two distinct flows occur to the east of Nethercote Model Farm. An extensive interbedded flow outcrops between Back Creek, a western tributary of Yowaka River, and Lochiel on the Pambula to Wyndham road, and continues to the "Six Mile" on the latter road. Other outcrops occur near the head of the Bald Hills Creek north of Pambula Trigonometrical Station, and west of the main road between the Saltwater Creek Bridge and the Mt. Gahan turn-off. These areas are shown on Plate xxxiii.

At Monga, south-east of Braidwood, a similar rock overlying the rhyolites is probably an extension of the outcrop described by H. I. Jensen (1908), and amygdaloidal basalts are interbedded with the Upper Devonian of the Yalwal series described by E. C. Andrews (1901).

The lower horizons of the basalt are more compact than those above, which are generally amygdaloidal, the amygdules consisting of epidote, calcite, chlorite and zeolites. Occasionally the rock is traversed by veins of fibrous asbestos and quartz, the asbestos fibres being at right angles to the length of the vein.

Under the microscope the rocks show some variations. They are all holocrystalline; the grainsize varies from very fine to medium; sometimes the rock is slightly porphyritic in plagioclase, and amygdaloidal structure is common. Most sections show at least a tendency to ophitic fabric, and one (M.808) is inclined to be variolitic.

Plagioclase occurs as idiomorphic laths, but rarely appears fresh. M.898 contains patches of fresh oligoclase, and other slides contain albite-oligoclase, but usually the felspar is albite, even in a fresh rock. Slides M.899 and M.900 show the complete replacement of plagioclase by epidote crystals, which are distinctly lighter in colour than the surrounding interstitial epidote. In one of the rocks analysed (M.938) there are a few phenocrysts of unaltered anorthoclase. The ferromagnesian mineral is colourless augite, allotriomorphic and interstitial; no fresh olivine has been observed, but pseudomorphs in serpentinous material and iron oxides indicate its former presence. Interstitial chloritic material is present in most sections, and vesicles contain calcite, epidote, chlorite and sometimes small quantities of a colourless radiating zeolite, with low double refraction, whose exact identity has not been determined.

The albitized nature of the felspars and the occurrence of calcite, epidote and alteration products in apparently fresh basalt are considered to be due to the action of deuteric agencies during the consolidation of the rock. The effects of this process are widely distributed and following the work of Bailey and Grabham (1909), Dewey and Flett (1911), A. K. Wells (1922-23), H. C. Sargent (1917) and others, albitization and kindred phenomena have been recognized in many rocks of all ages.

The occurrence of spilites in the Devonian rocks of the Tamworth district, described by W. N. Benson (1913, 1915*a*, 1915*b*, 1918) and in the Silverwood district of Queensland (Richards and Bryan, 1924) suggested the possibility of their occurrence among the Devonian rocks of the South Coast. However, a critical examination of the albitized basalts of the South Coast and a comparison with the published descriptions of spilitic rocks from Great Britain (H. Dewey and J. H. Flett, 1911, A. K. Wells, 1923), Eastern Fennoscandia (P. Eskola, 1925) and elsewhere indicates that the South Coast rocks are not true spilites, although they show some of their characteristics.

No pillow structure has been observed in the Nethercote basalts, although they are interbedded with red mudstones, and were formed in an area that was undergoing slow subsidence, and a change from freshwater to marine conditions. Like the spilites, they appear to be very altered, and the chief constituents are albitized plagioclase, augite and the remains of olivine, together with deuteric minerals (Sederholm, 1916).

Two analyses have been made of these rocks, one of relatively compact basalt, the other of a slightly amygdaloidal type. Since the minerals of the amygdules are regarded as essential magmatic products, they were not separated from the basalt, but were included in the rock analysed.

TABLE II.

	I	II	III	IV	V	VI	VII
SiO_2	46·28	49·87	54·10	49·35	51·14	48·22	53·41
Al_2O_3	16·02	15·91	16·45	17·61	14·47	14·82	11·58
Fe_2O_3	2·43	3·55	4·04	1·50	3·60	0·56	0·97
FeO	7·27	10·09	6·49	9·72	8·28	9·25	9·90
MgO	6·84	4·84	3·69	3·17	5·80	5·58	2·59
CaO	8·86	8·27	6·16	7·71	9·64	8·81	7·81
Na_2O	2·83	2·17	4·97	3·10	2·43	4·95	4·90
K_2O	0·25	1·10	1·01	1·56	0·57	0·44	0·82
H_2O+	3·65	2·44	1·01	2·56	2·52	2·54	$\left.\right\}$ 3·29
H_2O-	0·30	0·19	0·16	0·65	0·34	0·15	
CO_2	2·58	0·22	0·75	—	—	1·40	1·19
TiO_2	1·94	1·89	1·22	2·83	0·75	2·68	3·13
P_2O_5	0·34		0·26	tr.	0·08	0·23	0·36
MnO	0·11	pr	0·26	0·07	0·22	0·23	0·18
Other Const.				0·34	0·03	0·40	0·05
	99·70	100·54	100·37	100·17	99·87	100·26	99·78

TABLE OF NORMS.

	I	II
Quartz	1·08	4·92
Orthoclase	1·11	6·67
Albite	24·10	18·34
Anorthite	25·58	30·30
Corundum	1·73	—
Diopside	—	7·82
Hypersthene	25·42	20·63
Magnetite	3·48	5·10
Ilmenite	3·65	3·65
Apatite	0·67	—
Calcite	5·90	0·50
Class	'III	(II) III
Order	5	5
Rang	4	4
Subrang	4–5	4–5
Magmatic Name	Auvergnose	Auvergnose

I.—Amygdaloidal Basalt, east of Nethercote, Eden district, N.S.W. Anal. I.A.B.

II.—Compact Basalt, portion 68, Parish of Eden. Anal. I.A.B.

III.—Andesite (Spilite), Elbow Valley, Silverwood, Queensland. (Anal. ?). *Proc. Roy. Soc. Queensland*, 1924, xxxvi, No. 6, p. 88.

IV.—Melaphyre, Moroka Snow Plain, Victoria. Anal. G. Ampt. *Proc. Roy. Soc. Vict.*, xxxii, Part ii, 1920, p. 98.

V.—Albitic Dolerite, Loomberah, Tamworth district, N.S.W. Anal. J. C. H. Mingaye. PROC. LINN. SOC. N.S.W., xliii, 1918, p. 368.

VI.—Spilite, Frenchman's Spur, Nundle. Anal. W. N. Benson. PROC. LINN. SOC. N.S.W., xl, 1915, p. 139.

VII.—Ophitic Albite-Clinopyroxene rock. Spilitic lava bed in the Solomen Breccia, Solomen, western shore of Lake Onega. Anal. P. Eskola. *Fennia*, 45, No. 19, 1915.

The two analyses show variations compatible with mineralogical differences; the relatively greater abundance of chlorite, epidote and calcite accounts for the higher percentages of water and carbon dioxide in the amygdaloidal basalt. The analysis of a melaphyre from Moroka Snow Plain in the Mount Wellington district of Victoria, quoted in column IV, shows close resemblance to the Eden rocks, a feature which is interesting in view of their similar field associations and probable ages.

Compared with the two analyses of spilitic rocks quoted in columns VI and VII, the Eden rocks differ in exactly those respects which specially characterize the spilites. Although soda is dominant over potash, the alkalis are not particularly high, and the alumina of the Eden rocks is comparable to that of normal basalts, whereas the spilites are somewhat deficient in alumina. It is therefore evident that the Eden rocks are not true spilites, although they show some resemblances to rocks such as the albite-dolerite, whose analysis is quoted in column V, that are associated with the spilites.

There is also a general resemblance to the rock whose analysis is quoted in column III, which is regarded by H. C. Richards and W. H. Bryan (1924) as spilitic. This similarity is interesting as the rock is associated with spherulitic rhyolites of the Devonian series at Silverwood, Queensland.

THE AGE OF THE BASAL RHYOLITES.

The only direct evidence of the age of the igneous flows of the lower stage is that they overlie sediments of Silurian or Ordovician age with a marked unconformity, and underlie Upper Devonian sediments with a slight unconformity, indicated mainly by an erosional break. The general trend and dip of the igneous flows are approximately conformable with those of the overlying beds, suggesting that although erosion and probably vertical movement took place before the deposition of the red beds, the unconformity does not necessarily indicate a long time-interval between the two formations, say equivalent to that of the Middle Devonian Epoch, when enormously thick deposits of shales, limestones and tuffs were deposited in the Murrumbidgee area (L. F. Harper, 1909*a*). So far as the writer is aware there are no Middle Devonian sediments on the South Coast.

In the adjacent district in Victoria the Lower Devonian is represented by the Snowy River Porphyries, which are partly overlain by Middle Devonian sediments, as described by A. W. Howitt (1875), E. O. Teale (1920), and others. The dacites and quartz-porphyrites of Mt. Macedon (Skeats and Summers, 1912) and the Dandenong Hills, and the series of alkaline rocks of Mt. Leinster; Frenchman's Hill, Omeo; and Mt. Elizabeth, Noyang, have all been regarded as probably Lower Devonian (E. W. Skeats, 1909; T. W. E. David and E. W. Skeats, 1914, p. 305),

but the recent discovery by E. S. Hills (1929) may modify these correlations. Mr. Hills discovered fish remains of a typically Upper Devonian aspect in sediments underlying rhyolites that were "formerly believed to be Lower Devonian dacites". This important discovery "necessitates a revision of our conception of the age of the other Victorian dacites, and those that can be linked petrographically with the Marysville rocks must also be placed in the Upper Devonian".

An extensive flow of rhyolite occurs at the base of the Mt. Wellington series, and is chemically similar to the acid igneous rocks of the South Coast, with which it has been compared, page 475. E. O. Teale (1920, p. 125) calls attention to the fact that the rock is more acid than the Snowy River porphyries, and implies that petrological distinctions may be made. Teale regards the sedimentary series as Lower Carboniferous, but the Geological Survey map (1909) shows it as Devonian.

The Snowy River porphyries were considered by A. W. Howitt (1876-7) to be due to the activity of a line of volcanoes running approximately in a meridional direction near the course of the Snowy River. The distribution of the later Middle Devonian rocks both in Victoria and in New South Wales suggests that the occurrence of the Snowy River porphyries had a tectonic significance, foreshadowing the position of subsequent geosynclinal deposition during Middle Devonian time.

Since no Middle Devonian sediments occur above the lower igneous series of the South Coast, which might have been heralded by igneous activity, and since the series is comparable petrologically, chemically, and stratigraphically with the rhyolites of Mt. Wellington and probably those of Taggerty-Marysville, it is considered by the writer that these groups may be correlated, and that the Eden series and its equivalents along the South Coast may be regarded as the lowest stage of the Upper Devonian rocks on the South Coast of New South Wales.

Correlation of the Devonian Rocks of the South Coast.

From the descriptions in the preceding pages it is evident that outcrops of Upper Devonian rocks occur at a number of localities along the South Coast between the Shoalhaven River and the Victorian Border. Reference to the accompanying map (Plate xxxiv) indicates that the formations were deposited in a relatively narrow synclinal trough, whose axis was situated inland from the present coast-line. Subsequent earth movements produced folding of the sediments, the axes of the folds being approximately parallel to the trend of the structural depression in which the sediments were deposited. The arcuate character of the trough, which is emphasized by the arrangement of the trend lines, as shown on the map between Eden and Yalwal, suggests that a massif of older rocks existed to the east, which may have been portion of the Tasmantis of Süssmilch and David (1919, p. 277).

The Devonian rocks, which all belong to the Upper series, rest with a marked unconformity on a highly folded series of Pre-Devonian schists, phyllites and slates. The sediments contain plant remains and a marine fauna, which are typically Upper Devonian, and evidence has been produced in the previous pages to show that the underlying volcanic rocks are also probably of Upper Devonian age.

The most complete sequence occurs in the Eden district, where three stages of Upper Devonian series have been recognized, (i) a lower volcanic stage,

possibly of terrestrial origin, (ii) a middle stage of sediments and contemporaneous volcanic rocks, and (iii) an upper stage of marine, arenaceous sediments.

These three stages may be recognized at intervals along the South Coast, although the entire sequence is not always represented. The diagrammatic columnar sections (Text-fig. 3) of the areas previously described, illustrate the writer's opinion of the age relationships of the formations under consideration.

(i). It is proposed to call the lower volcanic stage the *Eden Stage* on account of its typical development in the vicinity of Eden. The distribution of the Eden stage is more limited than that of the succeeding stages; it outcrops at intervals along both sides of the zone of Upper Devonian sedimentation, occurring on the western side of the red beds south of Twofold Bay, and under the sediments of the Eden district; at Monga the basal Devonian rhyolite dips towards the east under the quartzites of the Clyde Mountain; and the quartz-felsite of Major's Creek, described by Professor David (1893*b*) is possibly a western extension of this occurrence. The quartz-porphyry indicated north-west of Yalwal on the map by Mr. Andrews (1901) may possibly represent the Eden stage. Along the eastern border of the Devonian trough the Eden stage is well developed in the neighbourhood of the Wandera Mountain, west of Buckemboura, and along the Lower Deua River and its tributaries.

Again at Tathra, east of Bega, and along the coast as far south as Bournda Island, the outcrops of "porphyry" and rhyolite are to be correlated with the lower or Eden stage. The maximum thickness of this stage varies from 450 feet in the Eden district to 800 feet along the Lower Deua River.

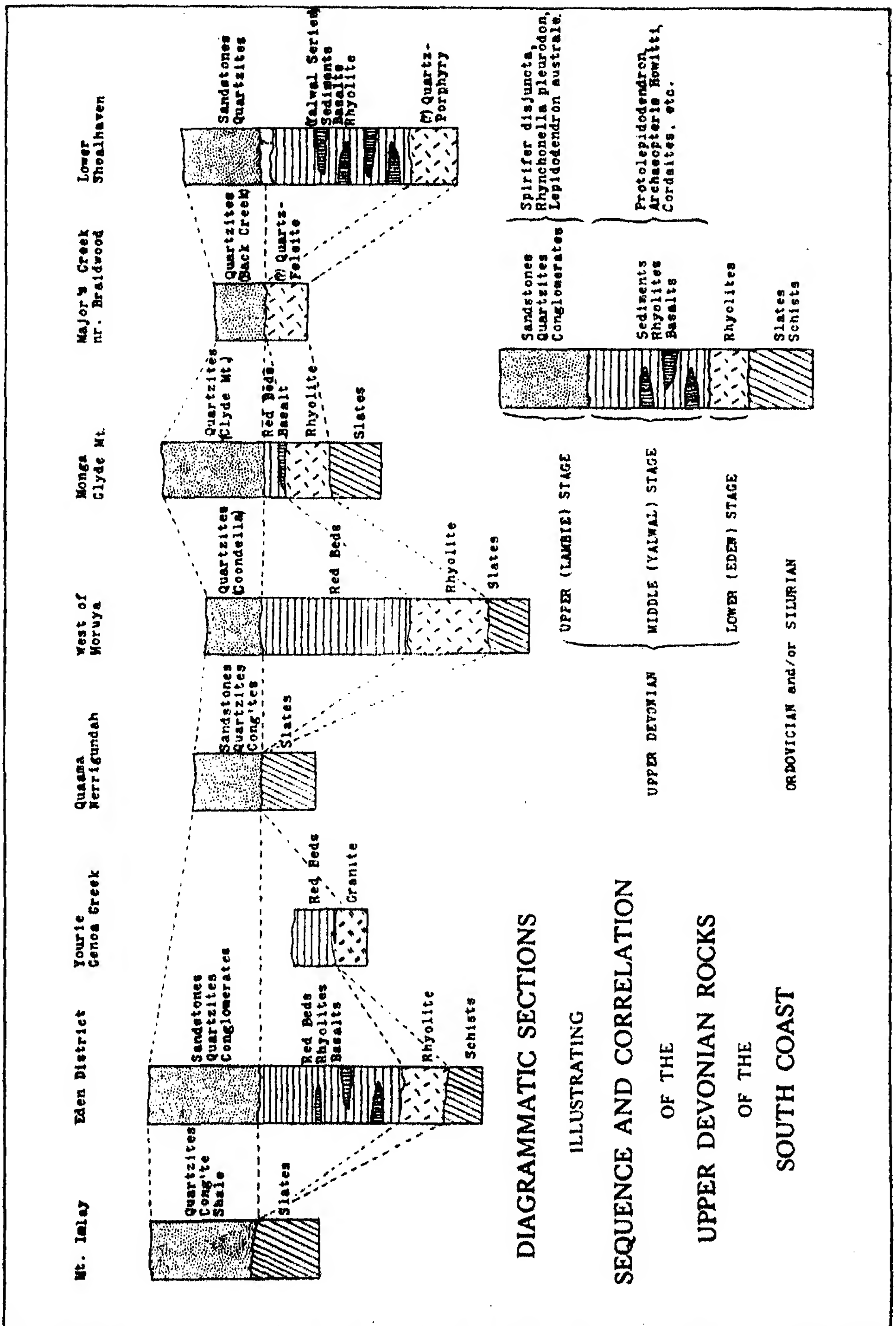
(ii). It has been shown that in the Eden district the middle stage is deposited over the eroded surface of the lower stage, and consists of a great development of red beds, with contemporaneous basalts, rhyolites and felsites. On account of the striking lithological resemblances to the series described by Mr. Andrews from Yalwal, confirmed by the occurrence of *Protolepidodendron* in the Eden and Yalwal beds, it is considered that the rocks are of similar age.

In the Eden district the middle stage attains a thickness of 1,500 feet and dips more or less conformably with the underlying igneous flows. Igneous action continued during the deposition of the red beds and produced interbedded flows of rhyolite, felsite and basalt. The red beds themselves may be of tuffaceous origin. The occurrence of basalts, related in some respects to the spilites, may be significant of the general movement of subsidence, which produced the marine transgression of the following stage.

The most extensive outcrops of the middle stage occur along the coast from Disaster Bay to the north of Merrimbula and inland through the Nethercote district.

Lithological similarities and the occurrence of Upper Devonian plant remains (*Cordaites*?) suggest the correlation of the Upper Genoa Creek beds and the middle stage of the Eden series.

Red beds of the middle stage occur in the Upper Brogo River and at Yourie, as well as along the Deua River Valley below Araluen. The thin series of red beds and basalts near Monga, occurring between the basal rhyolites and the Clyde Mountain sediments are considered to belong to the Yalwal stage, but evidently it thins out entirely before reaching Major's Creek, according to the section given by Professor David (1893*b*), (see Text-fig. 2, section 5).



Text-fig. 3.—Columnar sections illustrating sequence and correlation of the Upper Devonian formations of the South Coast.

Yalwal may be considered as the type locality for the rocks of this stage, and it is proposed to designate this the *Yalwal Stage*, defining the term to include the freshwater sediments, characterized by the presence of *Protolepidodendron*, *Archaeopteris Howitti*, *Cordaites*, and similar plant remains, together with contemporaneous lava flows.

(iii). Rocks that are lithologically equivalent to the Upper Stage of the Eden series have a more widespread distribution on the South Coast than either of the lower stages, since they overlap their outcrops and frequently rest directly and unconformably on pre-Devonian sediments. They consist essentially of conglomerates, grits, quartzites and mudstones of shallow water origin, and occasionally contain typical Upper Devonian marine fossils. No definite evidence of igneous action has been recognized in this stage on the South Coast.

Reference to the accompanying maps and sections shows that at Mount Imlay and along the ridge north of the Nullica River the Upper Stage rests on pre-Devonian formations, and similar relations occur east of Quaama and in the neighbourhood of Nerrigundah.

Along the Bendithera, Deua River and Clyde Mountain sections the marine beds overlie those of the middle (Yalwal) stage, but to the west of Monga, near Major's Creek, the middle stage is not represented and the marine stage rests on the quartz-felsite of the lower (Eden) stage. In the Shoalhaven district to the north there is a series of grits and quartzites from which a variety of Upper Devonian marine fossils, including *Spirifera disjuncta* and *Rhynchonella pleurodon*, has been collected by C. F. Laseron (1908). The exact field relations of these marine beds to the Yalwal beds have not been observed, but the lithological and palaeontological evidence strongly supports their correlation with the Upper and Middle Stages respectively, of the Eden district, thus placing the Devonian marine beds of the Shoalhaven River stratigraphically above the Yalwal beds.

In New South Wales the sediments outcropping at Mt. Lambie have been regarded as typical of the Upper Devonian of the south-eastern province (W. N. Benson, 1922). Compared with the Upper Devonian of the South Coast, it appears that only the Upper or Marine Stage is represented at Mt. Lambie.

As the origin, distribution, palaeontology and lithology of this stage are characteristic and distinct from those of the Eden and Yalwal stages, it is proposed to call it the *Lambie Stage*, understanding the term to apply not only to the sediments at Mt. Lambie, but to the whole of the marine stage of the Upper Devonian, which is stratigraphically above the Yalwal or middle stage of the Eden series.

The Lambie Stage is characterized by the presence of conglomerates, grits, quartzites and mudstones, in which a variety of marine forms is preserved. Typical fossils include *Spirifera disjuncta*, *Rhynchonella pleurodon* and *Lepidodendron australe*.

A review of the literature on the Upper Devonian rocks of New South Wales and Victoria suggests that the threefold division of the Upper Devonian series recognized on the South Coast may have more general application. Thus to the north of Yalwal, at Yerranderie, in the Upper Burragorang Valley, L. F. Harper (1930) shows (in section) the occurrence of a Devonian series of interbedded sediments and volcanic rocks underlying sediments containing Upper Devonian marine fossils. Upper Devonian sediments extend intermittently through the Kowmung Valley towards Hartley, Mt. Lambie, Capertee and Mudgee. Although the recorded Upper Devonian rocks of Mt. Lambie are chiefly marine sediments,

volcanic rocks occur immediately to the west, and may underlie the Lambie beds. This sequence is being investigated by the writer and Miss G. Joplin, B.Sc. From the Upper Macquarie Valley L. F. Harper (1909*b*) has described a series of Devonian rocks consisting of tuffs and contemporaneous lava flows of augite-andesite, felsite and rhyolite occurring beneath conglomerates, massive quartzites and sandstones containing *Rhynchonella pleurodon* and *Spirifera disjuncta*, a sequence which corresponds to that developed on the South Coast.

Maps of the Capertee district by J. E. Carne (1903) show a series of apparently unfossiliferous slates and sandstones separated by a belt of quartz-porphyry from a series of slates, sandstones and limestones from which a collection of Middle Devonian fossils was obtained (Carne, 1903, p. 125).

The whole series is regarded as Devonian and the occurrence of boulders containing *Spirifera disjuncta* in the overlying Permo-Carboniferous conglomerate indicates the existence of the Upper Stage of the Upper Devonian in the vicinity. The field relations of the quartz-porphyry to the Middle Devonian sediments on the one side and Upper Devonian (?) sediments on the other side are not definitely known, but the possibility of their analogy to the early Upper Devonian flows of the South Coast should be considered in future work in the district.

Records of the Devonian rocks of the Mudgee district include references to "andesites and rhyolites" (Benson, 1922, p. 103) which may correspond to the early Upper Devonian of South Coast. To the west of these areas the Devonian rocks consist mainly of arenaceous marine sediments of late Upper Devonian age.

In the adjacent areas in Victoria there are formations which appear to be analogous to the Upper Devonian rocks of the Eden district. These occur at Mt. Tambo, the Bemm River, Tabberabbera, Iguana Creek, and through the Mount Wellington and Mansfield districts, and have been described by a number of Victorian geologists including A. W. Howitt (1874-7), R. A. F. Murray (1877), E. O. Teale (1920), E. W. Skeats (1929), and many others. Palaeontological evidence of the age of these rocks is confined to fish and plant remains, and there appears to be no consensus of opinion regarding their age. This problem has been discussed recently by Professor Skeats (1929).

On the Geological Map of Victoria (1912) the beds round Mansfield are coloured as Carboniferous, and those to the south-east, surrounding Tamboritha and Wellington Mountains through to the head of the Avon River, Iguana Creek and the Tabberabbera districts are shown as Devonian.

The writer would tentatively correlate with the Lower (Eden) Stage of the Upper Devonian, the rhyolite of Lake Karng (Thiele, 1908, 1920) at the base of the Mt. Wellington series, and the rhyolites of the Taggerty-Marysville district (Hills, 1929*a*, 1929*b*), together with analogous volcanic rocks in Victoria.

The Middle Stage appears to be represented by the red and chocolate-coloured shales and sandstones of Iguana Creek, which contain *Cordaites australis* and *Archaeopteris Howitti*, and at Mt. Wellington and Snowy Bluff similar rocks are interbedded with rhyolites, felsites and basalts that are lithologically and chemically equivalent to those of the middle stage of the Upper Devonian at Eden. Probably at least portion of the Upper Devonian at Tabberabbera, described by Professor Skeats (1929), may be correlated with this stage.

A section through the lower part of the Upper Devonian at the Mitchell River, above Horseshoe Bend, is described as consisting of 350 feet of red and purple mudstones with thin bands of breccia and conglomerate and two flows of spherulitic rhyolite, followed by 70 feet of conglomerate and 500 feet of sand-

stone. The presence of melaphyre or altered basalt is suspected from boulders in the Mitchell River, but these have not been found *in situ*. Red mudstone, rhyolite-breccia and other specimens from this series, kindly lent to the writer by Professor Skeats, are remarkably similar to the South Coast rocks.

Similar red beds outcrop at Valencia Creek and Freestone Creek.

The Mansfield series of arenaceous sediments were classed by McCoy as the top of the Upper Devonian on the evidence of *Lepidodendron Mansfieldense* and a fossil fish. Later A. S. Woodward (1906) described the fossil fish as Carboniferous, and his classification is adopted by the Geological Survey. Professor Skeats (1929) points out that the absence of contemporaneous lavas in the sediments of the Mansfield region, as contrasted with the proved Upper Devonian beds of Victoria, may be regarded as evidence in favour of their possible Carboniferous age. It may be noted, however, that the upper stage of the Eden series is also devoid of igneous flows.

Lepidodendron australe, which was named and described by F. McCoy in 1874, was discovered in sandstones near the junction of Valencia Creek and the Avon River (Chapman, 1914). Regarding the stratigraphical horizon of the original specimen, R. A. F. Murray (1887) writes: "Professor McCoy expresses a strong opinion as to the Lower Carboniferous aspect of this fossil plant impression; and from my own observations I am inclined to believe that the beds in which it is found are among the uppermost of the group, and younger than, though conformable with, the Upper Devonian Beds of Freestone and Iguana Creeks." Since then *Lepidodendron australe* has been found at four other localities in the Macallister basin by E. O. Teale (1920), who tentatively regarded the Mt. Wellington beds as Lower Carboniferous, as they had not been distinguished from the Mansfield formation. In New South Wales *Lepidodendron australe* occurs in association with marine Upper Devonian fossils at a number of localities, as recorded by David and Pittman (1893), and its occurrence does not imply a Carboniferous age.

The Upper Devonian beds of Perry, South-eastern Maine, contain a form *Leptophloeum rhombicum*, which D. White (1905, pp. 72-73) regards as equivalent to *Lepidodendron nothum* Feistmantel and *Lepidodendron australe* McCoy.

The evidence of the Upper Devonian of the South Coast of New South Wales naturally suggests that similar conditions of sedimentation prevailed in the adjacent district of Victoria, and that two stages of sedimentation are represented here also, the lower (Yalwal) stage containing only remnants of a primitive land flora, being of lacustrine or estuarine origin and including interbedded acid and basic lava flows; and the upper (Lambie) stage consisting of arenaceous marine sediments, without evidence of igneous activity.

Tectonic History and Palaeogeography.

The examination of the Devonian rocks of the South Coast and their comparison and correlation with other Devonian formations in south-eastern Australia has led to a consideration of the general problem of the palaeogeography and geological history of this portion of the continent during Devonian time.

Professor W. N. Benson (1922, 1923) has already given a comprehensive account of Devonian sedimentation and tectonic structure, based on his own extensive researches and a careful survey of the previous literature, notably the work of W. B. Clarke (1860–1878), T. W. E. David (1893*a*, 1911, 1914), H. I. Jensen (1911), E. C. Andrews (1914, 1916*b*, 1922), and many others to whom reference is made.

The additional Devonian occurrences described in the present paper give evidence for an elaboration of the known stratigraphical succession of Upper Devonian rocks, and provide a means of more direct correlation of some of the known deposits in south-eastern Australia.

After the deposition of Ordovician and Silurian sediments, violent earth-movements affected the greater part of south-eastern Australia and the rocks were intensely folded. The axes of folding usually run in a meridional direction in New South Wales and in eastern Gippsland, Victoria, but in the western part of Gippsland the trend is more to the north-west. The Devonian formations usually rest with a marked unconformity on the eroded surface of the older formations.

In the Walhalla-Wood's Point district in Victoria, however, the Centennial beds contain evidence of continued sedimentation from Silurian into early Devonian time, as shown by the work of E. W. Skeats (1928) and W. Lang and I. Cookson (1930). Similar relations may obtain between the Silurian and Devonian at Bowning in the Yass district, New South Wales, according to J. Mitchell and W. S. Dun (1920).

Otherwise Lower Devonian unconformably overlie the Silurian and older rocks and are represented only by igneous rocks, typically the Snowy River porphyries. The dacites of Mt. Macedon (Skeats, 1909; Skeats and Summers, 1912) and elsewhere in Victoria have been regarded as Lower Devonian, but the recent discovery by E. S. Hills (1929) of Upper Devonian fish remains in sediments below rhyolites "formerly believed to be Lower Devonian dacites" casts some doubt on the age of analogous rocks. In New South Wales the volcanic series of Murrumbidgee (Harper, 1909; Shearsby, 1905) are considered to be Lower Devonian.

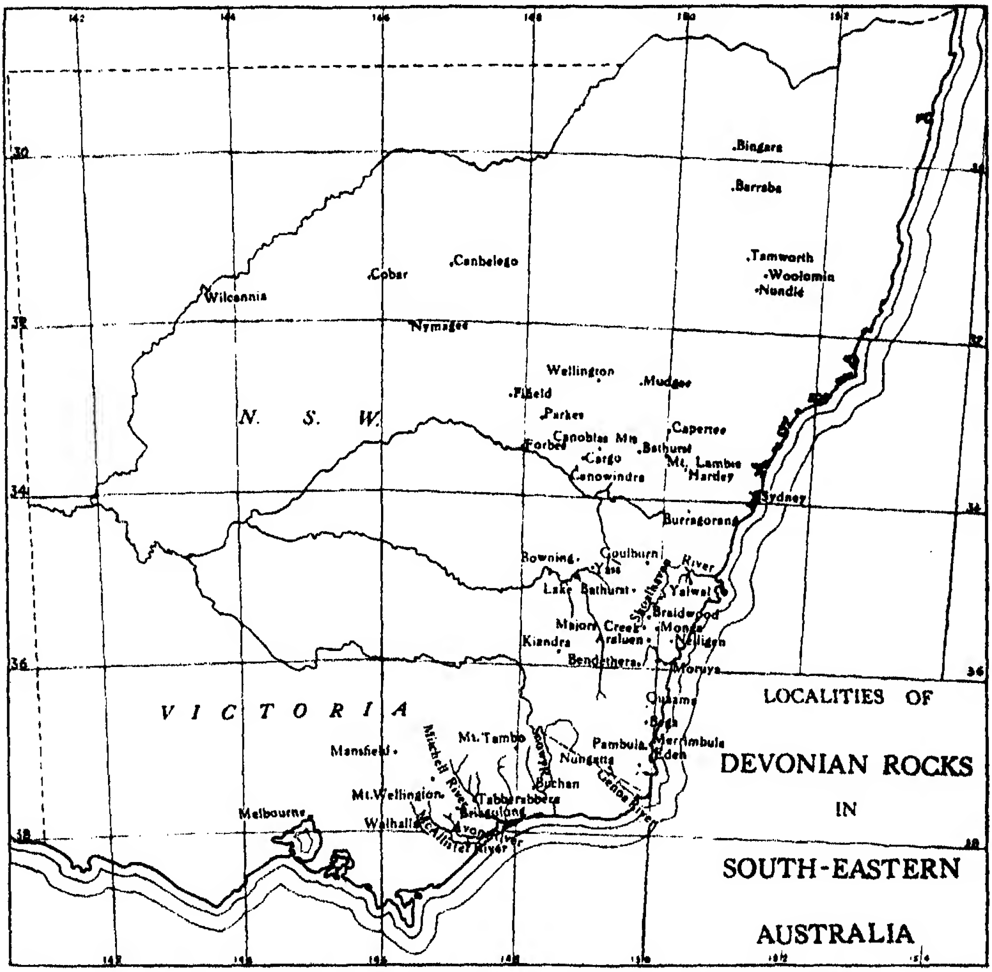
The sketch map (Text-fig. 4) shows the distribution of the known outcrops of Devonian rocks in Victoria and New South Wales, the information being taken from the State geological maps of 1909 and 1914 respectively, modified by reports subsequent to their publication.

The distribution of the Lower Devonian volcanic series appears to have a tectonic significance, probably being related to the trough-faulting and down-warping that produced the narrow gulf in which the Middle Devonian sediments were deposited. This gulf extended in a northerly direction from Victoria into New South Wales, including the areas of Buchan, Bindi, Tabberabbera, Limestone Creek, Lobb's Hole, and the Murrumbidgee, near Yass.

The Middle Devonian beds consist of shales, massive limestones, tuffs and acid volcanic rocks. At Buchan the series rests in hollows eroded out of the underlying Snowy River Porphyries. In the Murrumbidgee basin a rich and varied fauna has been preserved, more than a hundred forms being recorded by W. N. Benson (1922, pp. 95-96). Mr. Dun suggests (E. C. Andrews, 1916*b*, p. 757) that detailed examination of the fossils of the Murrumbidgee beds may show that Lower Devonian beds pass up into Middle Devonian, the whole series attaining a thickness of 14,000 feet, according to L. F. Harper (1909*a*).

There is some uncertainty as to the limits of the Middle Devonian gulf in New South Wales. Other Devonian limestones are recorded from many localities by Carne and Jones (1919), but no further details of their stratigraphical position are given, as palaeontological evidence of their age is scarce. These limestones occur in two main areas, one being the belt from Mudgee to near Capertee, and the other being in the neighbourhood of Goulburn and Tarago.

The Devonian rocks of the Capertee district were described and mapped by J. E. Carne in 1903. An assemblage of typical Middle Devonian fossils was obtained from the limestone at the Blue Rocks (Carne, 1903, p. 125), but the existence of Upper Devonian beds in the locality is indicated by the presence of *Spirifera disjuncta* in boulders in the overlying Permo-Carboniferous conglomerate, although the form has not been found *in situ*.



Text-fig. 4.—Sketch map of south-eastern Australia, showing localities of fossiliferous Devonian outcrops.

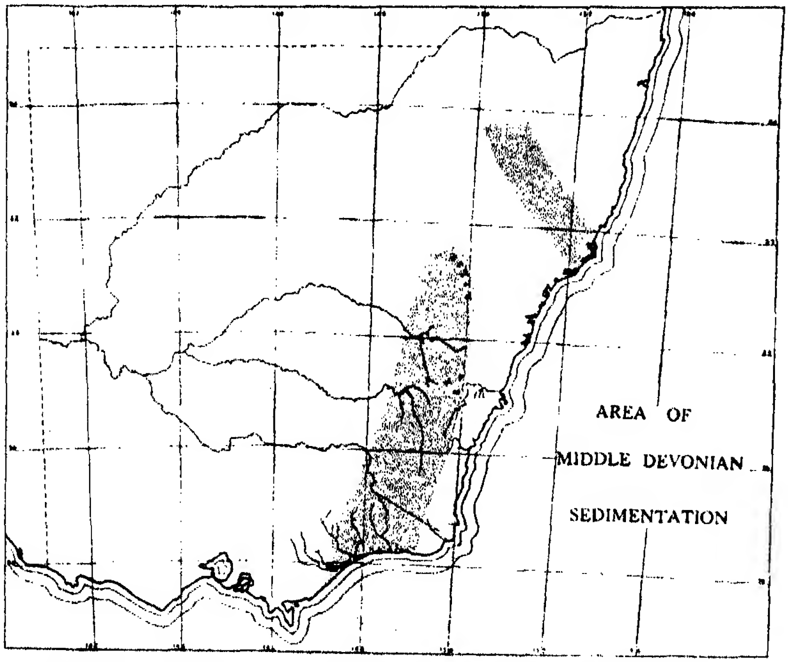
This area is therefore one of exceptional interest, for it seems probable that the relations between the Middle and Upper Devonian may be revealed in this locality.

The limestones of the Goulburn-Tarago district have been classed as Devonian mainly by their lithological associations; the only fossils known are from the outcrops west of Lake Bathurst Railway Station, described by J. E. Carne and L. J.

Jones (1919, pp. 136–137). From these beds Mr. Dun has identified *Receptaculites*, *Cyrtoceras*, dendroid *Favosites* and (?) Coral, which again have a Murrumbidgean aspect, although Upper Devonian sediments are known to occur in the vicinity.

There appears to be no authentic record of massive coralline limestone in the Upper Devonian of New South Wales, at least south or west of the Permo-Carboniferous basin. Some of the New England limestones are classed as Upper Devonian by W. S. Dun (1914, p. 292), but these are included in the Tamworth series of Middle Devonian by W. N. Benson (1922).

Otherwise Upper Devonian sediments are typically arenaceous, and the probability of conditions suitable for the growth of corals seems remote. The available evidence therefore indicates that the massive Devonian limestones of the Mudgee-Capertee and Goulburn-Tarago districts are Middle Devonian, and were formed in part of the Murrumbidgean gulf. The strike directions of these rocks shown on the map (Text-fig. 5) are taken from the published records of Carne and Jones (1919).



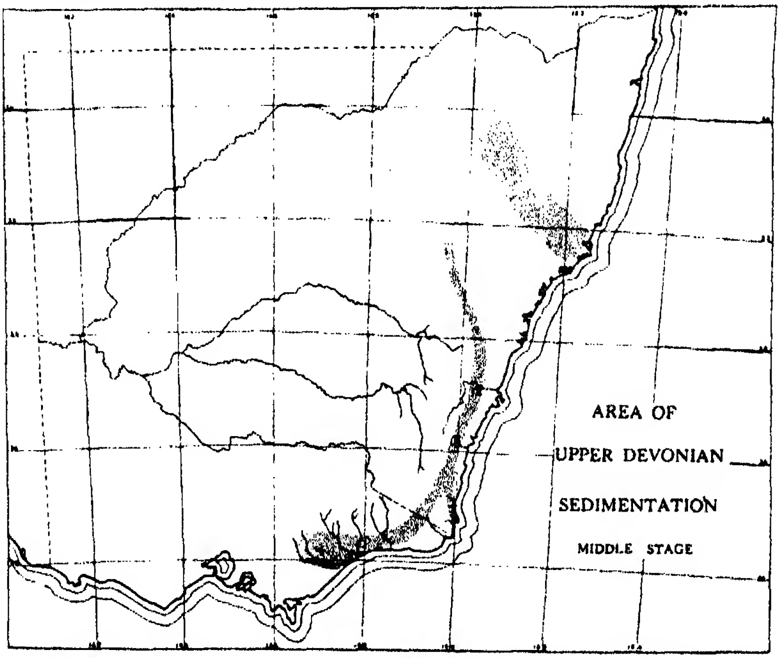
Text-fig. 5.—Sketch map of south-eastern Australia, showing area of Middle Devonian Sedimentation.

The distribution of the outcrops of Upper Devonian sediments (Text-figs. 6, 7) and the more intense folding of the Middle as compared with the Upper Devonian beds, indicates that the Murrumbidgean geosyncline suffered compression from the east at the close of the Middle Devonian, when the greater part of the former gulf was converted into dry land, most of which was not covered by the Upper Devonian sea.

This closing Middle Devonian orogeny is of considerable importance, inasmuch as it finally welded on the eastern massif to the growing Australian continent, and marked the close of an era of general compressive force from the east

indicated by the pronounced meridional trend of the Lower Palaeozoic rocks of south-eastern Australia. The trend-lines of the newer formations show progressive change from the meridional direction to north-north-west and north-west, the initial variation commencing in the Upper Devonian epoch. The strong unconformity between the Middle and Upper Devonian exposed by the Mitchell River below Tabberabbera (Skeats, 1929) is additional evidence of late Middle Devonian diastrophism.

The Upper Devonian commenced with an outburst of volcanic activity represented by extensive rhyolitic flows of the Eden Stage along a zone nearer the present coastline of south-eastern Australia than the former area of Middle Devonian deposition. These volcanic rocks may be traced from Mt. Wellington, Victoria, along the coast of New South Wales from Disaster Bay to Yalwal, thence inland through Burragorang, west of Mt. Lambie, and towards Capertee and



Text-fig. 6.—Sketch map of south-eastern Australia showing area of Upper Devonian Sedimentation (Middle Stage).

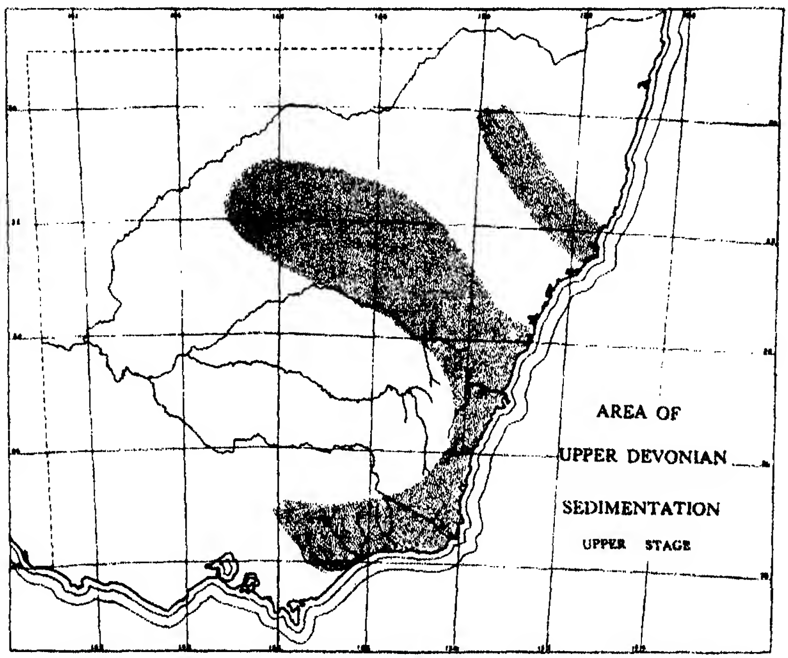
Mudgee. No centres of volcanic activity have been recognized; indeed, it seems more probable that the flows were due to fissure eruptions associated with faulting that preceded the formation of the depressed area in which the later sediments were deposited.

The probable position of this zone is indicated in Text-figure 6, and it forms the first approximation to the development of the important geosyncline in which the Upper Palaeozoic and Mesozoic sediments of eastern Australia were deposited. The gradual movement of the axis of the geosyncline to the north and east is an important tectonic feature in the building of Australia, which has been recognized by T. W. E. David (1893*a*) and E. C. Andrews (1914, 1916*b*).

The middle or Yalwal stage of the Upper Devonian followed the trend of the previous stage and consists of lacustrine or estuarine deposits, characterized by a

great development of red beds, mudstones, sandstones and grits, and contains fragmentary plant remains but no marine organisms. Igneous activity continued through the middle stage, rhyolites being interbedded with basalts allied to spilites.

Continued subsidence caused marine transgression over the greater part of New South Wales in the upper (Lambie) stage of the Upper Devonian (Text-fig. 7). The marginal trough of the previous stage appears to have survived, and the greatest sedimentation took place in this zone; arenaceous sediments of the order of 1,200 feet in thickness remain in the southern part of the State. At Mt. Lambie the thickness was somewhat greater, although recent work by Miss G. Joplin, B.Sc., and the writer indicates that previously the thickness of the Lambie series has been considerably over-estimated.



Text-fig. 7.—Sketch map of south-eastern Australia showing area of Upper Devonian Sedimentation (Upper Stage).
Note.—Other outcrops coloured as Devonian on the State Geological Map of New South Wales consist chiefly of unfossiliferous quartzites.

The lithology of this stage is characteristic: coarse conglomerates, purple sandstones and quartzites predominate. There appear to be no massive coralline limestones throughout the Upper Devonian. Marine fossils are abundant in certain thin zones, and may form local shell-beds, but great thicknesses of sediment are unfossiliferous. Drift *Lepidodendron australe* occurs in this stage.

Outliers of Upper Devonian rocks have been described from Molong-Canoblas (C. A. Süssmilch, 1906), Upper Macquarie (L. F. Harper, 1909*b*), Parkes-Forbes (E. C. Andrews, 1910), Cobar and Canbelego (E. C. Andrews, 1913*a*, 1913*b*), and Wellington, N.S.W. (A. J. Matheson, 1930), and other occurrences are recorded in Reports of the Geological Survey of the Mines Department, New South Wales.

Probably the Lambian sea extended almost as far west as the Darling River (Text-fig. 7) and a veneer of arenaceous sediments was deposited over the pre-Devonian rocks. In the Cretaceous conglomerates west of the Darling River, boulders of fossiliferous Upper Devonian rocks have been found (J. B. Jaquet, 1892; W. S. Dun, 1898*b*), but according to E. J. Kenny (1929, 1930), probably no outcrops of proved Devonian sediments occur beyond 50 miles west of Cobar.

No igneous flows are known to occur in the upper stage of Upper Devonian sedimentation, which was succeeded by a period of great orogenic earth-movement, termed by C. A. Süssmilch (1914) the Kanimbla Epoch. Folding of the Upper Devonian during this epoch was accompanied by the intrusion of enormous granodioritic batholiths in the area under consideration, and its description may well form a separate chapter in the geological history of the State.

Summary.

The paper describes the occurrence of the Devonian rocks of the South Coast of New South Wales, between the Shoalhaven River and the Victorian Border. The field-relations and associations of these rocks are described from a number of localities, and the petrological and chemical characters of the igneous rocks are discussed.

It is shown that the sediments were deposited unconformably on the older Palaeozoic formations, probably in a narrow geosynclinal trough, whose axis was inland from the present coast-line.

The rocks belong to the Upper Devonian Series, which is represented by three stages on the South Coast: a lower stage of acid volcanic rocks, a middle stage of freshwater or estuarine sediments with contemporaneous acid and basic lavas, and an upper stage of marine sediments containing no igneous rocks. These are called the Eden, Yalwal and Lambie Stages respectively.

The formations are correlated with a number of other occurrences of Devonian rocks in south-eastern Australia.

The discussion of the tectonic history of the series has led to a consideration of the palaeogeography of the Devonian system in south-eastern Australia. It is considered that the occurrence of the Snowy River porphyries, of Lower Devonian age, had a tectonic significance, indicating the position of subsequent deposition of the Middle Devonian sediments.

A survey of available literature suggests that the Middle Devonian gulf or sea was more extensive than has been supposed formerly, and that all the massive coralline limestones of Devonian age in New South Wales belong to the Middle Series.

The relations of the Middle and Upper Series have not been recorded in New South Wales, although a study of the palaeogeography indicates that their relations may be revealed in the Mudgee-Capertee and Goulburn-Tarago districts. It is considered that the unconformity at Tabberabbera, Victoria, is of more than local significance, being additional evidence of the diastrophism which finally welded on the south-eastern part of Australia to the growing continental mass. The trends of the Upper Devonian rocks on the South Coast are directed along the margin of this mass, and are the earliest indication of the position of the geosyncline in which the Permo-Carboniferous System of eastern Australia was deposited. During the upper (Lambie) stage of the Upper Devonian, represented

chiefly by arenaceous sediments, marine transgression took place over a considerable area in New South Wales.

The paper is illustrated by a series of palaeogeographical maps, and geological sketch-maps and sections of the Eden-Wolumla district and of the South Coast between the Shoalhaven River and the Victorian Border. For the latter maps the parish and county maps of the Department of Lands, Sydney, were used as a geographical basis. Some geological information was obtained for the area north of Bateman's Bay from L. F. Harper's map of the Southern Coalfield of New South Wales, 1915, and from reports of the Department of Mines, New South Wales. The results of the published work of the writer on the igneous rocks of the Milton (1925), Moruya (1928) and Mt. Dromedary (1930) districts are incorporated. Otherwise the mapping is the result of the writer's field-work, which has not been published previously. The known Devonian outcrops are distinguished from the older Palaeozoic sediments, and the outcrops of the granitic batholiths are shown more accurately than on the existing Geological Map of the State, although no specific reference to them has been made in the present paper.

ACKNOWLEDGMENTS.

In conclusion, the writer wishes to thank those who have assisted in the preparation of this paper, especially Professor L. A. Cotton, M.A., D.Sc., in whose department the laboratory work was carried out, and Assistant Professor W. R. Browne, D.Sc., for friendly interest in the work. She is indebted also to Mr. W. S. Dun for assistance in palaeontology and to Professor E. W. Skeats, D.Sc., for specimens of and information concerning Devonian rocks of Victoria.

During the course of the field-work, the writer was accompanied on one occasion by Miss G. Joplin, B.Sc., and on another by Miss M. Turkington, B.A., to both of whom she tenders her thanks. Finally to residents of the South Coast, including Mr. and Mrs. J. R. Logan and family of "Edrom", Twofold Bay; Mr. L. and Miss Mitchell of Lower Towamba; Mr. and Mrs. W. I. Swinnerton of Eden, and many others who willingly gave every possible assistance during the field-work, the writer records her sincere thanks.

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EXPLANATION OF PLATES XXX-XXXIV.

Plate xxx.

1.—Cliff below the Eden Lighthouse, showing the junction between the older Palaeozoic sediments and the overlying columnar rhyolite of Upper Devonian Age.

2.—Cliff section north of Tathra showing unconformity between the older Palaeozoic sediments and Upper Devonian rhyolite.

3.—Cliff south of the Eden Lighthouse, showing columnar structure in the rhyolite.

Plate xxxi.

1.—Section at "Edrom", Twofold Bay, showing the eroded upper surface of the rhyolite overlain by basal conglomerate of the middle stage of the Upper Devonian.

2.—Cliff section below the Convent, Eden, showing "red-beds" of the middle stage of the Upper Devonian deposited against the eroded surface of the rhyolite of the lower stage (see text).

3.—Road cutting, 22 miles from Moruya towards Araluen, showing ripple-marks in highly-folded Upper Devonian sediments.

Plate xxxii.

1.—Rock-platform at Munganno Point, Twofold Bay, showing large spherulites in rhyolite.

2.—Polished section of large spherulite from Munganno Point, showing central amygdule of banded chalcedony, concentric secondary structure of the spherulite, which has not entirely obliterated the original flow-lines of the rhyolite. ⅜ natural size. Photo. H. G. Gooch.

Plate xxxiii.

Geological Sketch Map of the Eden District.

Plate xxxiv.

Geological Sketch Map of the South Coast between the Shoalhaven River and the Victorian Border.

AN INVESTIGATION OF *LOBELIA GIBBOSA* AND *LOBELIA DENTATA*. I.

Mycorrhiza, Latex System and General Biology.

By Lilian Fraser, B.Sc.

(Forty-four Text-figures.)

[Read 25th November, 1931.]

Introduction.—The mature plant.—The seedling stage.—The root system and mycorrhiza.—The shoot system.—The latex system.—General biology, experiments and observations.—Discussion.

Introduction.

The investigation here reported was commenced in Adelaide early in 1916. Miss A. Rennie, working under the direction of Professor Osborn, began an examination of *Lobelia gibbosa* Labill., and made a study of its latex system and a preliminary examination of the fungus present in its roots. She also made a number of field notes on the growth habits of the plant, and some experiments. This work was not published.

In the summer of 1929 Professor Osborn noticed that *Lobelia dentata* Cav. growing in the Sydney district had a number of interesting and peculiar features in common with *Lobelia gibbosa*; and on his advice an investigation was made of both species, and the work previously done by Miss Rennie was confirmed and extended.

The present communication includes the results of both investigations, Miss Rennie having generously handed over her notes, drawings and preparations to the author, who wishes to acknowledge her indebtedness for them.

Text-figures 37–40 are from drawings made by Miss Rennie. The author alone is responsible for any opinions expressed.

The Mature Plant.

Lobelia gibbosa Labill. is reported for all the Australian States, including Tasmania. In South Australia, where part of the work was carried out, it is reported by Black (1922) as occurring on Kangaroo Island, Yorke and Eyre Peninsulas and probably in the south-west. The material for the present work was collected in the scrub at Mt. Lofty, near Adelaide.

Bailey (1900) and Ewart (1930) distinguish three varieties of this species of *Lobelia*, the one here described corresponding to var. *microsperma*, but Black (1922) gives *microsperma* as a synonym for *gibbosa* and distinguishes no varieties. Ewart considers that the species is composed of a complex of hybrids.

L. gibbosa is an annual herb, growing in both sandy and clay soil, often in colonies. The stem is erect and usually unbranched, except sometimes in the region of the inflorescence. It is somewhat turgid and succulent, with a length underground of 2–5 cm., occasionally more. The leaves are all cauline and vary

with the habitat, from filiform or linear in poor or exposed situations to narrow lanceolate in sheltered positions, and are somewhat fleshy. The inflorescence is a scorpioid cyme, resembling a terminal one-sided raceme, bearing numerous crowded china-blue flowers which conform to the general *Lobelia* type. Latex is present throughout the whole of the plant, and is especially abundant in the above-ground parts.

The height of the plant was found to vary very much with its habitat, the average is about 47 cm., but in exposed situations it may not be more than 10 cm. If germination takes place early, or in a sheltered position, a tall fleshy stem bearing well developed lanceolate leaves is formed, whereas if germination is late or the plant is in an exposed position, the stem of the mature plant is much shorter and the leaves much narrower. The quantity of anthocyanin pigment developed in such exposed plants is usually quite high, often giving the whole plant a distinct reddish tinge.

The underground part of the stem is white, fleshy and brittle. The roots are whitish when young, and very brittle, relatively infrequently branched, and of a very uniform diameter of 1–1·5 mm.

The feature which first attracted attention to this species was the fact that, at the time of flowering, the leaves, roots and lower parts of the stem are withered and practically dead, the root system and underground part of the stem appearing to serve no function beyond that of holding the plant upright in the soil. Another peculiar characteristic is that material collected for herbarium specimens continues to grow in the press, and to open its flowers, often until no buds remain unopened. Bailey (1900) remarked on these unusual features: "Few plants", he wrote, "are as tenacious of life as this species of *Lobelia*. The root is most delicate and only seems of use to the plant up to the time of the first flower opening, after which it appears to die, and only by being fixed in the ground keeps the plant in an upright position. When preparing herbarium specimens of it, they must be scalded before placing in the papers, otherwise they keep elongating and expanding flowers until the plant is thoroughly exhausted, which takes frequently several weeks."

L. gibbosa is rare and sporadic in the Sydney district. Here a rather similar species, *L. dentata* Cav., is common on the sandstone country. It is found all along the coast and main divide of New South Wales and southern Queensland in sandy soil.

L. dentata differs from *L. gibbosa* in the following features: the flowers are larger and deeper blue, on longer pedicels and less crowded on the axis of the inflorescence; the leaves are ovate and more or less deeply incised; the aerial stem is not fleshy, and it does not increase in length, nor do flowers open in herbarium folders.

Unlike *L. gibbosa*, its stem may be quite frequently branched, below or above the ground level, as well as in the flowering region. Frequently, however, it also may have only a single unbranched stem.

In the field *L. dentata* is found growing practically exclusively in sandy loam soil.

The size and general appearance of *L. dentata*, like *L. gibbosa*, are regulated to some extent by its habitat; plants growing in exposed positions are typically smaller than more sheltered plants, and also have a considerable amount of anthocyanin pigment present in their leaves. The length of the underground stem shows

more variation in this species than in *L. gibbosa*; sometimes it may be only about 2 cm., but not uncommonly it reaches 15 cm. or even more in length.

In general, the more favourable the position in which a plant is growing, the longer is its root system functional, and the longer does it remain flowering. In some cases plants which had opened more than twenty flowers still had a growing root system, whereas unfavourably situated plants usually were found to have a withering root system even before the first flower was opened. In the field it was often possible to locate plants which had healthy root systems by an examination of their above-ground parts. They were, as a rule, rather succulent in appearance, with deep-green stem and leaves, whereas plants whose root systems were beginning to wither had paler green, often reddish, and curled leaves, and thinner stems.

The root system, even of large plants, was not often found to extend more than 10 cm. around the plant, and for small plants the radius was often not more than 5 cm. The roots are exceedingly brittle and it was found to be extremely difficult to wash out even a small portion of the root system unbroken. The roots are much interwoven, often in tangled bundles, and rather infrequently branched as compared with the roots of most herbaceous dicotyledons. Their diameter is strikingly uniform, about 1·1 or 1·2 mm., except at the growing apex, where they taper to a short point. Even the main root is very little thicker, and frequently cannot be distinguished from its branches. The roots are creamy-brown when old, and opaque white near the apex, unless they have ceased growing, in which case the apex of the root is also creamy-brown in colour.

On two occasions plants were collected which had no chlorophyll at all and were a watery purple colour. One had just appeared above the ground, but the other was nearly 8 cm. tall and fairly robust. Both were collected in sheltered situations.

The Seedling Stage.

The seeds of both these species of *Lobelia* are exceedingly small. Fifty seeds of *L. dentata* were measured by means of an ocular micrometer and their average length was found to be 0·31 mm., the maximum was 0·39 mm. and the minimum 0·28 mm.; the width varied from 0·21 mm. to 0·29 mm., with an average of 0·25 mm. Their weight is correspondingly small; 100 seeds of *L. dentata* were found to weigh slightly under 1 mgm., so the average weight of a single seed would be slightly less than 0·01 mgm.

To obtain thin sections of the seeds it was found necessary to adopt the following procedure. The seeds were first soaked in water for a day, they were then fixed in formalin acetic alcohol, washed and placed in 5% caustic potash for seven days; after this they were thoroughly washed in water and then taken up to paraffin. After this treatment sections 6 μ thick could be cut fairly readily.

The structure of these minute seeds is very simple; in Text-figure 1 a median longitudinal section is shown. There is a rugose coat of two layers, an outer one (O), a single layer of thick-walled cells, and an inner one (I), which is crushed so that its structure cannot be made out. This encloses an endosperm tissue of fairly large cells, packed with oil. Embedded in this endosperm, near to the micropylar end, is an embryo (E), which consists of much smaller cells and is totally undifferentiated into plumule and radicle.

As yet germination of the seeds in the laboratory has not been accomplished. In nature the wastage of seeds must be great. In most years *L. dentata* is locally

abundant during the summer months in sandy loam soil. Each plant produces 1–20 or more capsules, each of which contains, on an average, in the neighbourhood of 150 seeds. It is at once evident that only a small fraction of this number must develop into plants for next season, especially since, as will be described later in detail, vegetative propagation is not uncommon in this species. Because of this wastage, and because of the peculiar nutrition of the growing plant, it was not expected that, whatever the conditions necessary for germination may be, they will be found at once experimentally. The following description is therefore based on an examination of seedlings collected in the field.

L. dentata will first be described. The youngest seedlings found were entirely subterranean, and the search for them was rendered doubly difficult by their extreme brittleness. Even when seedlings were dug up whole in sods of earth, and dissected out or washed out in the laboratory most carefully, the shoot was often damaged in the process, and in no case was a complete root system obtained.

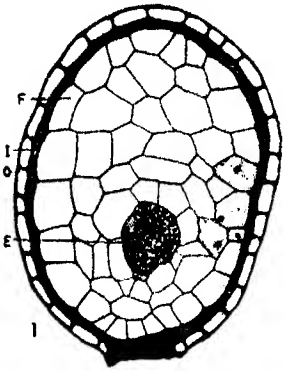
The youngest seedling found is shown in Text-figure 2; the shoot (S) is fairly long and somewhat twisted and bears rudimentary leaves (L), the root (R) is broken off short leaving only a small fragment still attached to the shoot. The seedling was almost transparent, so that after soaking for a short time in caustic potash, it was washed in water and mounted whole in glycerine jelly; the details of its anatomical structure could then be made out without difficulty under the microscope. Text-figure 3 shows an enlargement of the basal part of the plant shown in Text-figure 2; the root (R) is broken across at E, and on the left of the part of the shoot (S) which is included, is a rudimentary leaf (L); the cotyledons are represented only as small emergences (C), and the vascular strand (V) can be traced throughout the whole structure. The most interesting feature is associated with the hypocotyl region, a length of about 0·3 mm.; the cortical cells here are much elongated in a transverse direction. Associated with this hypocotyl region were found twisted strands of fungal hyphae (F in Text-fig. 3); these could not be easily freed from the root, and moreover were constantly found in association with the hypocotyl in numbers of other young plants examined.

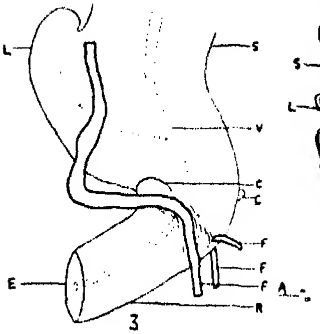
It was seen that where the fungus rhizomorphs came in contact with the plant, they spread out over its surface, forming a practically continuous, closely interwoven mat of hyphae; part of this is shown at F in Text-figure 4. This covering was only present over a short length of the plant and was always associated with the transversely elongated cells of the hypocotyl.

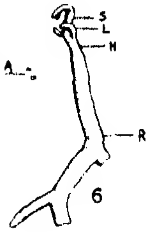
Part of a transverse section of the hypocotyl is shown in Text-figure 5; the mat of fungal hyphae on the outside is fairly thick, and in places is seen to have forced its way into the interior. This it has done by growing down between the cells of the cortex (C), and it has spread throughout the cortex, remaining strictly intercellular in position. It is most abundant in the outer cortex, where it forms a wide network between the cells. The outer part of the fungal mat (M) is composed of narrow, thick-walled closely interwoven hyphae, but the inner hyphae (I) and those which invade the root are very much enlarged, thin-walled and densely protoplasmic.

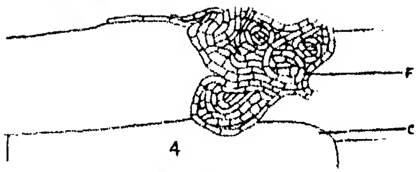
An examination of older seedlings shows that the root system is usually quite large and extensive before the young shoot has attained any great size. It consists of a mass of roots of even diameter, twisted and rolled together in strands and knots. The roots have a very smooth external appearance, and

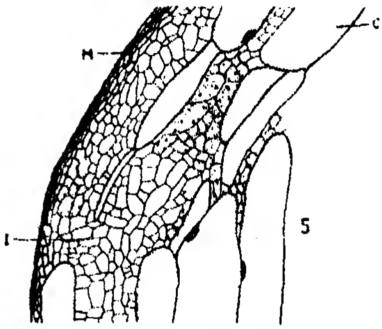
though exceedingly brittle, each individual fragment of root is easily freed from particles of soil since there are no root hairs developed at any time.

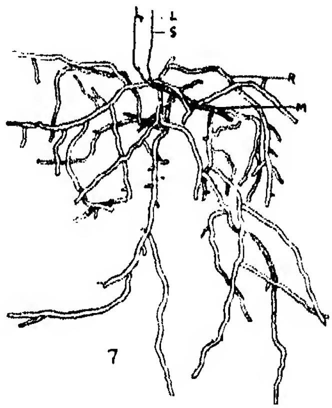












Text-fig. 1.—A longitudinal section of a mature seed of *Lobelia dentata*. O, outer layer of testa; I, inner layer of testa; F, endosperm; E, embryo. × 140.

Text-fig. 2.—A subterranean seedling of *L. dentata*. S, shoot; L, rudimentary leaf; H, hypocotyl; R, root. × 1·1.

Text-fig. 3.—An enlargement of the hypocotyl and part of the root and shoot of the seedling shown in Text-fig. 2. S, shoot; L, rudimentary leaf; R, root; C, rudimentary cotyledons; E, broken end of root; V, vascular strand; F, fungal strands. × 26·5.

Text-fig. 4.—Part of the hypocotyl area of a seedling of *L. dentata*. F, fungus mat over the surface; C, transversely elongated cortical cells. × 250.

Text-fig. 5.—Part of a transverse section of the hypocotyl of a seedling of *L. dentata*. C, cells of the cortex; M, external mat of fungal hyphae; I, invading fungal hyphae. × 250.

Text-fig. 6.—A subterranean seedling of *L. gibbosa*. R, root; S, shoot; L, rudimentary leaf; H, hypocotyl; A, seeds of *L. gibbosa* drawn to the same scale. × 3·5.

Text-fig. 7.—Part of the root system of a fairly large plant of *L. dentata*. S, base of underground stem with rudimentary leaves (L); M, main root; R, lateral roots. × 0·67.

The smallest seedling found of *L. gibbosa* is shown in Text-figure 6; it is smaller than any of the seedlings found of *L. dentata*, and was discovered by accident during the washing out of the root system of a larger plant. It shows indications of a fairly large root system (R), but the shoot is still rudimentary. Fortunately Miss Rennie, who discovered the specimen, mounted it complete in glycerine jelly, and on examination of the hypocotyl region a structure was observed quite similar to that shown by the seedling of *L. dentata* in this area. There is a region of transversely elongated cells, the surface of which is covered by a fungus mat, and there is also an associated strand of fungal hyphae.

Root System and Mycorrhiza.

Text-figure 7 shows part of the root system of a plant of *L. dentata* washed out from sandy soil; it represents less than half of the total number of roots and few of the branches are intact, but it brings out clearly the uniform diameter of the roots, and the method and frequency of branching.

The internal structure of the roots is quite simple; the lateral roots have invariably a diarch xylem, but in the main root the xylem is usually 3–4-arch, latex vessels are present in the phloem in the position of sieve tubes, the endodermis is unthickened and the cortex fairly wide. Secondary thickening takes place only in old roots and new elements are added to both xylem and phloem.

The size attained by subterranean seedlings as compared with the size of the seeds from which they develop is very striking. The seedling illustrated in Text-figure 6 was the smallest found, but it is relatively enormous in comparison with the two seeds (A) drawn to scale beside it. On account of this great difference in size between the seed and the colourless seedling resulting from it, it was suspected from the beginning of the investigation that the species of *Lobelia* under discussion were mycorrhizal. Miss Rennie succeeded in demonstrating the presence of a fungus in the roots of *L. gibbosa*, but did not make a detailed examination of it.

This has now been done for *L. dentata* and confirmed for *L. gibbosa*, and there is every reason for believing that the two species are identical in this respect.

The presence of a fungus in the root tissues of *Lobelia* is readily demonstrated, but the amount found in various sections and the condition in which it was present, were found to be very variable, and seemed to conform to no rule. In some cases only a trace of mycelium was present in the outer part of the cortex; in other cases it was found to be more generally distributed. Finally it was found necessary to fix the material in the field, and to choose long complete pieces of root, cutting sections at intervals from the apex to the older parts.

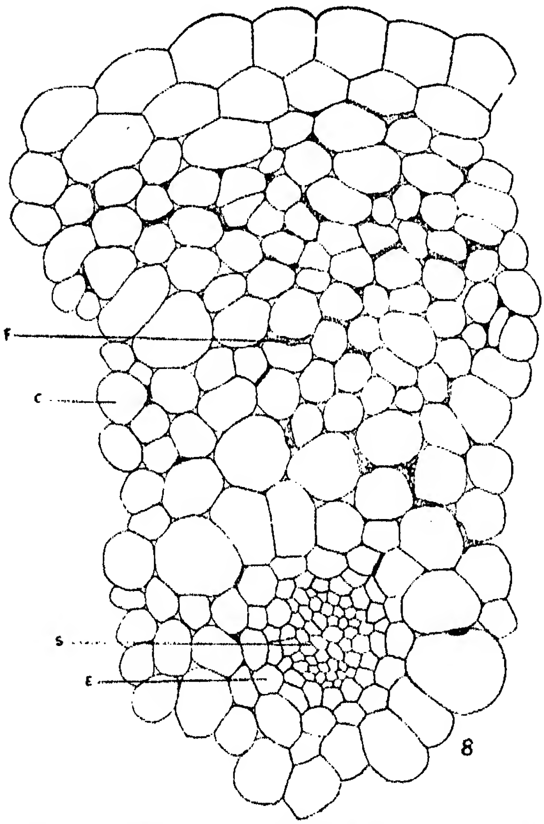
It was found that when material is brought into the laboratory for examination in the living condition, changes often, though not invariably, take place, principally the total disappearance of all reserve food from the fungus, thus giving an entirely wrong impression of the condition of the fungus within the root as growing in the field. Sections of roots which are not actively growing also tend to be misleading.

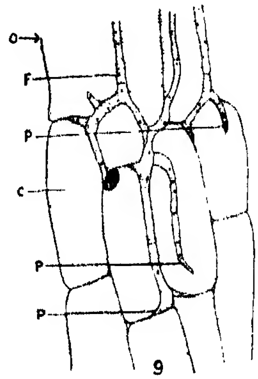
Flemming's weak fixative was found to be best for roots and young stems, and its fat staining property was very useful in the case of young roots. Sections were stained with Gentian Violet and Orange G, or if, as was the case for young roots, much oily reserve food were present, the sections were simply stained

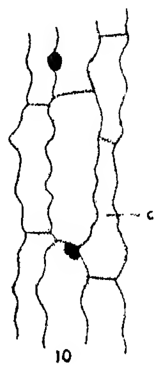
with Orange G or Erythrosin; material fixed in chromo-acetic fixative was best stained by the iron alum haematoxylin method.

The development of the fungus within the root.—The following description and figures of the development of the fungus within the root are of *L. dentata*; *L. gibbosa* is substantially the same and will not be separately described.

Text-figure 8 shows part of a transverse section of a growing root taken about 7 mm. from the apex. The cells of the stelar region (S) are as yet practically undifferentiated; the cells of the cortex are fairly large and there is no sign of root hairs. In the cortex, fungal hyphae (F) can be readily distinguished; they are strictly intercellular, and though many sections were examined, no sign of







Text-fig. 8.—Part of a transverse section of a young root showing the stage of fungal invasion. S, undifferentiated stele; E, endodermis; C, cells of the cortex of the root; F, fungal hyphae. × 250.

Text-fig. 9.—Part of a radial longitudinal section of the middle cortex of young root showing the fungal hyphae growing down between the cells of the cortex. C, cortical cells; F, fungus; O, older part of root; P, pointed growing apices of the fungus. This was drawn from a section which was cut rather thick for the purpose of examining the growing points of the fungus. Those hyphae, therefore, which appear to be penetrating into the cell cavity are in reality outside the cell wall. × 250.

Text-fig. 10.—Part of a tangential longitudinal section of the outer cortex of a very young root showing cortical cells (C) with sinuous radial walls. × 250.

haustorial organs could be discovered. A longitudinal section in this region (Text-figure 9) shows that the fungal hyphae are growing down from the older part of the root. They are fairly narrow and densely protoplasmic, with rather pointed growing apices (P), and they force their way down between the cells of the middle cortex. This may be called the region of fungal invasion.

In a tangential section very near the apex of a growing root, and above the fungus, the outer cells of the cortex are seen to have curiously sinuous radial longitudinal walls (Text-figure 10); this curvature becomes more and more pronounced further from the apex. It becomes still more marked when the fungus grows down between the cells, and the penetrating fungal hyphae have a correspondingly sinuous course (F in Text-figure 11). In a radial section the walls of these cells are often cut so that they resemble a string of small cells end to end, sometimes with patches of mycelium between them (C in Text-figure 14). As seen in the radial longitudinal section shown in Text-figure 14, the tangential walls of these cells are occasionally slightly sinuous also (S). It is only the outer two or three layers of cortical cells which show this feature. The inner cortical cells at first have quite straight longitudinal walls (Text-figure 9), though they later become somewhat distorted by the intercellular growth of the fungus. There is no possibility of this phenomenon being the result of faulty fixation or embedding, since it was observed in all longitudinal sections cut, and in preparations of living roots. It proved to be a feature of some importance in the identification of small subterranean *Lobelia* seedlings.

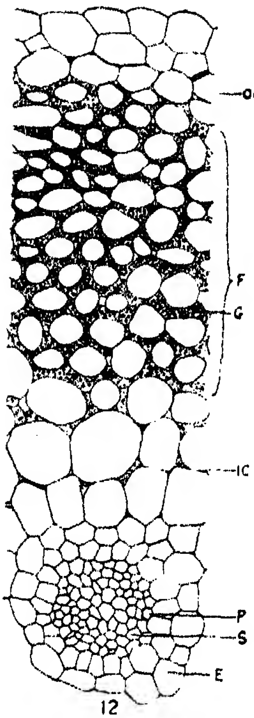
A section taken about 3 cm. from the root apex shows the next stage in the development of the mycorrhiza (Text-figure 12). This may be called the period of fungal enlargement. In a region which may be called the fungal zone, limited in most cases to the middle cortex, there has been a great concentration in the amount of fungal tissue present. The individual hyphae are much wider than in the region of fungal invasion, and a good deal of branching has taken place. The cortical cells are often forced apart, and in transverse section appear as practically isolated islands in the mass of fungal tissue. At this time the fungal hyphae stain much more darkly with osmic acid than they do in the region of fungal invasion. This is due to the presence in them of small darkly staining droplets of reserve food material.

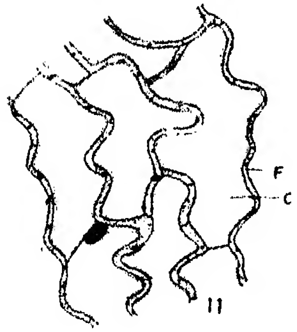
A tangential section of the middle cortex at this stage (Text-figure 13) shows the fungal hyphae forming a network between the cortical cells, branching and anastomosing in all directions. Text-figure 14 shows part of a radial longitudinal section of a root at a slightly earlier stage than that shown in Text-figure 12;

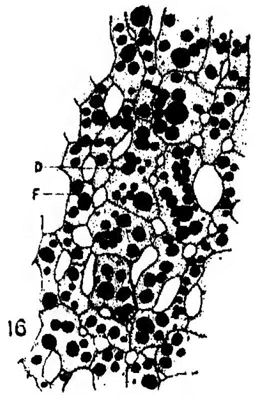
Text-fig. 14.—Part of a radial longitudinal section of a young growing root during the period of fungal enlargement. E, endodermis; I.C, inner cortex; O.C, outer cortex; F, fungal zone; C, the cut edges of the walls of the sinuous walled cells of the outer cortex; S, slightly sinuous tangential walls of the cells of the outer cortex. × 150.

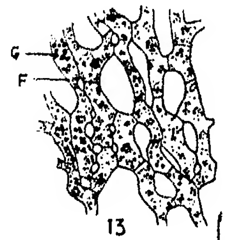
Text-fig. 15.—Part of a radial longitudinal section of a young growing root showing the final development of the fungus during the period of fungal enlargement. It shows the large size of the droplets of reserve food in the hyphae of the fungal zone as compared with those in the hyphae of the inner and outer cortex, and the great enlargement of the fungal hyphae in the fungal zone. O.C., outer cortex; I.C., inner cortex; f, fungal zone; D, droplets of reserve food; E, endodermis; F, fungal hyphae. × 270.

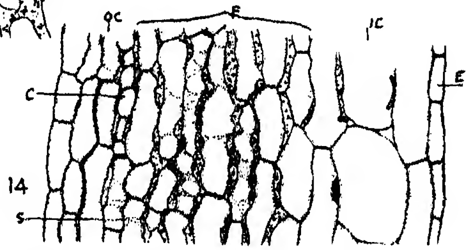
Text-fig. 16.—Part of a tangential section of a young growing root in the fungal zone showing a dense network of fungal hyphae with large accumulations of reserve food. F, fungal hyphae; D, droplets of reserve food. × 435.

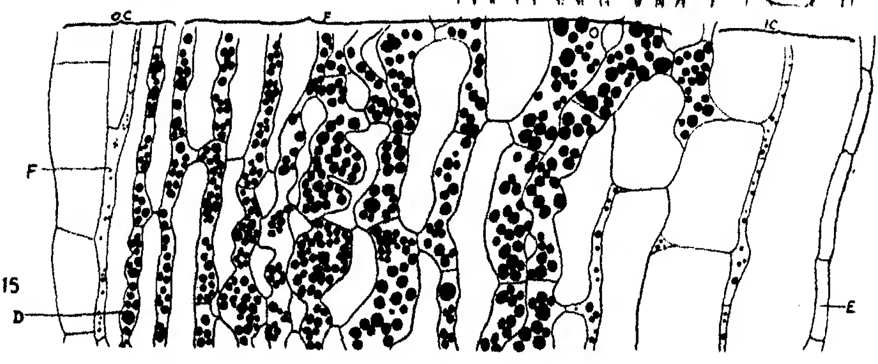












Text-fig. 11.—Part of a tangential longitudinal section of the outer cortex of a slightly older root than that shown in Text-fig. 10, showing that the radial walls are even more sinuous, and that the fungal hyphae between them are correspondingly sinuous. C, cortical cells; F, fungal hyphae. × 270.

Text-fig. 12.—Part of a transverse section of a young growing root showing the commencement of the period of fungal enlargement. S, stele; P, protoxylem; E, endodermis; I.C, inner cortex; O.C, outer cortex; F, fungal zone; G, small droplets of reserve food accumulating in the hyphae of the fungal zone. × 150.

Text-fig. 13.—Part of a tangential longitudinal section of a young growing root in the fungal zone during the period of fungal enlargement, to show the formation of a network of hyphae between the cells of the cortex. F, fungal hyphae; G, droplets of reserve food. × 270.

concentration of the mycelium has begun in the fungal zone (F), and small droplets of reserve food material are present. Both longitudinal and transverse sections fail to show any signs of the development of fungal haustoria into the root cells. These cells appear to be perfectly healthy, the nucleus shows no sign of distortion and is usually somewhat fusiform, cytoplasm lines the cell wall, but there is no sign of reserve food (Text-figs. 8, 14).

Text-figures 15 and 16 show respectively radial and tangential longitudinal sections of a root showing the maximum development of the fungus in the fungal enlargement stage. In Text-figure 15 the differentiation of the cortex into three zones, outer and inner cortex and fungal zone, is clearly brought out. The fungus in the outer and inner cortex has much less reserve food than the hyphae in the middle cortex. Here the fungal hyphae are much extended by the presence of the reserve food which has accumulated in much larger droplets than elsewhere. Text-figure 16 shows a small part of a tangential section taken in the fungal zone; the mycelium forms a practically complete network and shows the great distortion caused by the accumulation of reserve food in its cells.

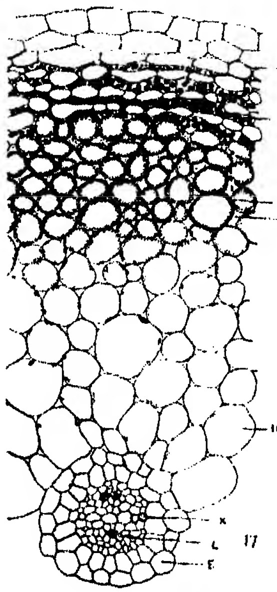
The third stage of the mycorrhiza may be called the period of fungus depletion, and its progress is shown in Text-figures 17 and 19, which were taken respectively 4 cm. and about 6 cm. from the apex of an actively growing root. It will be seen at once that the cells of the inner cortex are much enlarged and there is scarcely any trace of fungal mycelium between them. Important changes are also evident in the inner part of the fungal zone; the cortical cells in this region have enlarged somewhat, and in the cytoplasm lining their walls are numerous, small droplets of a reserve food similar in staining properties to that of the fungal hyphae. Between these cells the hyphae appear somewhat compressed and have lost practically all their reserve food. Depletion of the fungus is most marked in the innermost part of the fungal zone, and the hyphae in the inner cortex are so crushed as to be practically invisible. The process of the depletion of the fungal hyphae is shown in greater detail in Text-figure 18. At A the fungal hyphae are much distended by the presence in them of large accumulations of reserve food, and the cortical cells between are rather distorted, but otherwise appear quite healthy; there is no sign of fungal haustoria. At B droplets of reserve food are beginning to appear in the peripheral cytoplasm of the cortical cells and the fungal hyphae between them are slightly narrower than at A, and have less reserve food. At C one can see that the fungus has lost all reserve food, and though still densely protoplasmic, is being gradually crushed by the expansion of the cortical cells. The nuclei of the cortical cells remain quite unaltered in shape and size during this period.

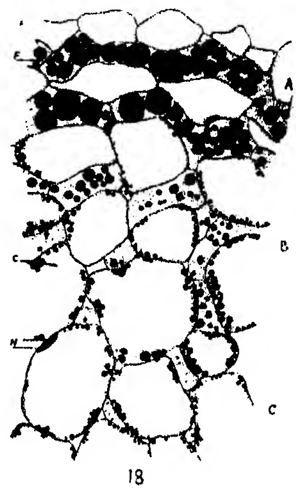
The process of depletion of the fungal hyphae and engorgement of the cortical cells goes on progressively towards the outer cortex. Its progress may be traced in sections cut further and further from the apex of the root till finally all reserve food is seen to have disappeared from the fungus; during this period the cortical cells extend and the hyphae between them are so compressed that they are hard to detect. Concurrently with this change the latex vessels in the phloem come to contain material which stains darkly with osmic acid (Text-figs. 17, 19); from this it appears that the food material absorbed from the fungus by the cortical cells is transported away at once.

In older roots no sign of the fungus can be detected except in the outermost region of the cortex where a few threads of it persist, apparently in the living condition. Text-figure 19 shows the final stage of the fungus depletion period.

A few drops of reserve food are still present in the outermost cells of the fungal network (D), and the latex vessels are densely staining, evidently in the process of transporting away food materials.

Throughout this description it has been emphasized that these are the changes which occur in an actively growing root. In roots which are growing slowly, the changes described may be telescoped into a much shorter length of root, and in the sections cut of roots which had ceased to grow, it was seen that the fungal hyphae were entirely devoid of food materials.





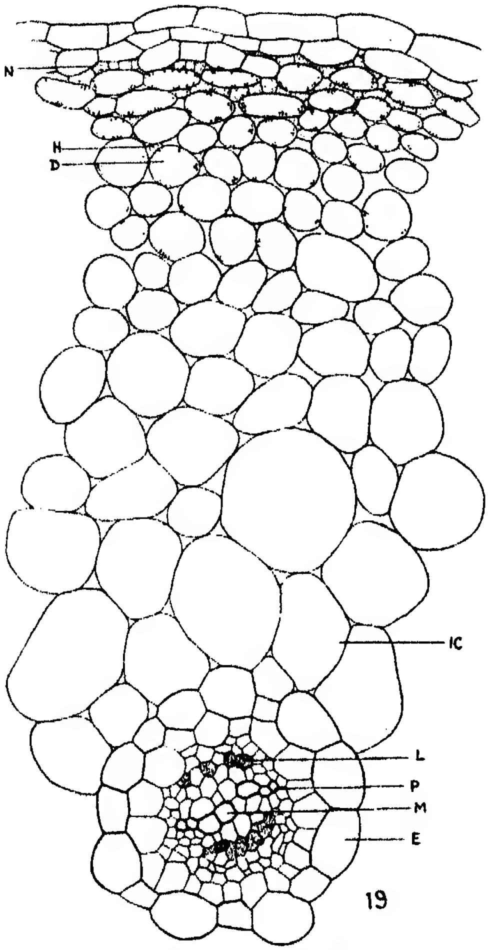
Text-fig. 17.—Part of a transverse section of a young growing root showing the commencement of the period of fungal depletion. X, protoxylem; L, latex vessels; E, endodermis; I.C, inner cortex; O.C, outer cortex; D, cortical cells of inner fungal zone showing accumulations of droplets of reserve food in their peripheral cytoplasm; H, depleted fungal hyphae between these cells. U, unaltered hyphae in outer fungal zone.

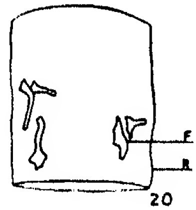
Text-fig. 18.—Part of the section shown in Text-fig. 17 showing in greater detail the process of depletion of the fungal hyphae. At A the fungal hyphae are unaltered and the cortical cells between them are devoid of food material. At B some of the reserve food has gone from the hyphae and droplets are appearing in the peripheral cytoplasm of the neighbouring cells. At C all reserve food has gone from the fungus. F, fungal hyphae; N, nucleus of cortical cell; C, cortical cell. × 300.

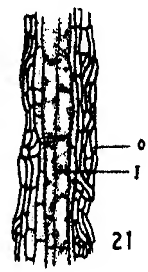
As was previously stated, it was found that the colour of the root is a reliable guide to its internal condition; clean opaque white roots are in the fungus enlargement condition, creamy roots are in the fungus depletion condition, and the fungus within brownish-cream roots is entirely depleted of food material. Roots with brownish-cream tips have ceased growth, and sections taken of these show no sign of the presence of reserve food material.

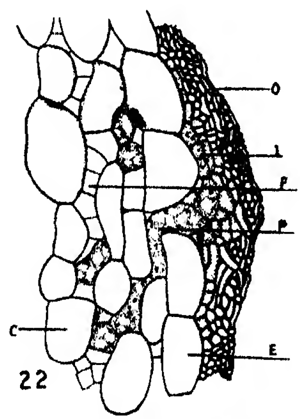
Occasionally roots have been found which are rather thinner than usual, and nearly hyaline. These were always associated with plants which had developed an aerial shoot. When sections of these were examined it was found that they

showed no trace of the fungus, and also lacked sinuous-walled cells in the outer cortex. A similar kind of root developed when plants brought in from the field were planted in pots and allowed to grow in a glasshouse under good conditions.









Text-fig. 19.—Part of a transverse section of a young growing root showing the final stage of the period of fungal depletion. P, protoxylem; M, metaxylem; L, latex vessels; E. endodermis; I.C, inner cortex; D, cortical cells in the outer part of the fungal zone with few peripheral droplets of reserve food; H, depleted and crushed hyphae between them; N, living and uncrushed, but depleted fungal hyphae in the outer cortex. × 150.

Text-fig. 20.—Part of a root of *L. dentata* showing a number of associated strands of fungal hyphae (F). × 14.

Text-fig. 21.—A longitudinal section of a fungal rhizomorph. O, outer layer of hyphae; I, inner hyphae. × 270.

Text-fig. 22.—Part of a transverse section of a root of *L. dentata* passing through the point of entry of a strand of fungal hyphae. O, outer layer of hyphae; I, inner hyphae; F, invading strand; E, epidermis; C, cells of the cortex of the root. × 270.

On one occasion three plants from the same locality were examined and it was found that they had developed roots which were slightly narrower than the typical roots and, though white near the apex, were not quite opaque. These roots were evidently in a condition of active growth, and an intercellular mycelium was found to be present, which invaded newly-formed tissues by growing downwards from the older part of the root. After invasion the fungus increased in amount in the inner cortex and subsequently became crushed out, just as is the case in a typical root. These roots differ from the typical roots in that they show little or no sign of the accumulation of a reserve food in the intercellular fungus nor of the transference of food materials from the fungus to the cells of the cortex of the root. On the occasion when these plants were found other plants were collected in the same locality whose roots showed the typical accumulation of oily reserve food in the intercellular fungus, and the subsequent transference of this to the cells of the cortex of the root.

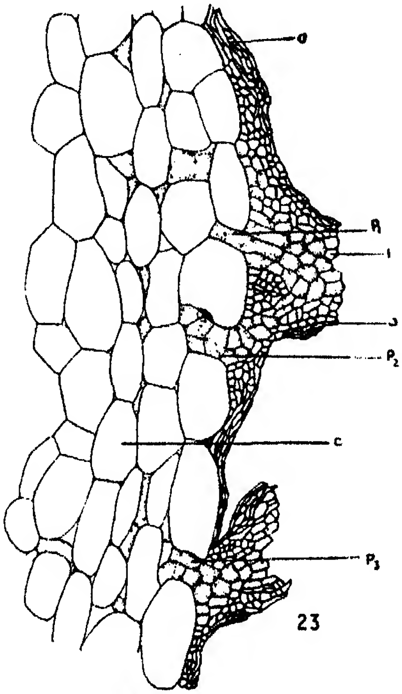
The invasion of the root by fungus strands growing in the soil.—Although numerous sections of roots were examined, no trace of an external mycelium could be discovered until pieces of root were examined whole under the microscope. It was then immediately found that associated with the roots were very narrow rhizomorph-like strands of fungal hyphae similar to those found in connection with the hypocotyl of seedlings. As a rule these did not spread out very far over the surface of the root (Text-fig. 20).

The number of fungus strands per unit area of root is very variable. Sometimes a large number are found close together, as shown in Text-figure 20, at other times lengths of as much as 5 cm. of root were examined and not a single fungus strand was discovered. The fungus strands are brown and brittle, breaking off close to the root very easily. Generally they are most abundant on the older parts of the roots, and only very rarely were any found in association with the first 2–3 cm. of a growing root.

The fungus rhizomorph resembles the mat of fungal hyphae covering the hypocotyl in that it consists of two parts, an outer and an inner (Text-fig. 21). The outer layer (O) consists, as in the fungus mat, of thick-walled, narrow hyphae, running in a general longitudinal direction, but in places much twisted. This forms a continuous tissue over the core of the strand, which consists of one or more longitudinally running hyphae (I) which are much wider than those of the outer tissue, and are thin-walled, densely protoplasmic and multinucleate.

When one of these strands grows into contact with a *Lobelia* root, the thick-walled hyphae of the outer layer spread out over the surface of the cortex, forming a mat which may be extensive or, more usually, is quite small. The cells of the core come into direct contact with the outer cells of the root. From this core a strand of the fungus, usually consisting of a single hypha, more rarely of two or more, grows down between two epidermal cells and into the cortex of the root crushing out the hyphae of the fungus which had grown down within the root from the hypocotyl. Text-figure 22 is part of a transverse section of a root showing the outer cortex and an associated strand of fungal hyphae which is cut obliquely. A single penetrating hypha (P) has grown down from the strand into the cortex of the root. Between the cells of the cortex two kinds of fungal hyphae can be distinguished: one is densely protoplasmic and evidently is connected with the outer hyphal strand; the other (F), the hyphae previously present in the root, has very little protoplasm. In Text-figure 23 a more complex and less usual

condition is shown. Above a branched strand is penetrating the root in two places, P1 and P2; P2 is a complex structure consisting of several hyphae. Below another fungal strand is present which also has a compound penetrating strand, P3.



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Text-fig. 23.—Part of a transverse section of a root of *L. dentata* showing the entry of several strands of fungal hyphae. O, outer layer of hyphae; I, inner hyphae; P1, P2, P3, invading strands of hyphae; C, cortical cells. × 250.

Except in places where branching took place (Text-fig. 23), only one place of entry into the root could be found for any one fungus strand; it seems, therefore, probable that the growing point of the rhizomorph becomes modified and penetrates into the root rather than that the rhizomorph runs along the surface of the root, having several points of entry.

The Shoot System.

a. External Structure.

Lobelia dentata.—The shoot at first grows much more slowly than the root. The plant illustrated in Text-figure 2 had a comparatively large root system, which unfortunately was damaged when it was being excavated. The shoot increases in diameter, becoming more and more succulent and brittle. It remains almost transparent, but before long a central white strand is visible: this is the stele.

The general habit of the young plant appears to depend largely on the type of soil in which it is growing. In light sandy loam *L. dentata* has usually a single straight shaft, rarely branching except in the flowering zone (Text-figs. 24, 25).

But seedlings were found, when excavating in heavy sandy clay, which showed a rather different habit of growth. Usually they were more succulent and of greater diameter than the first type. They occasionally have a simple unbranched shoot, such as shown in Text-figure 26, but more often the shoot is profusely branched at varying levels below the surface of the soil (Text-fig. 27). Text-figure 27 illustrates an entirely subterranean seedling, and its size, compared with that of the seed from which it originated, is very remarkable. Nearly always these seedlings are gnarled and twisted (Text-figs. 27, 28).

At this stage the latex vessels in the stem are well developed and their contents stain darkly with osmic acid and with iodine, but have not the milky-white appearance of the latex of the mature plant. If a living subterranean shoot be cut across, a little watery white fluid oozes out from the stele, but the greatest amount of bleeding is from the cut cells of the cortex. When the *Lobelia* shoot grows above the surface of the ground, leaves are expanded and become green, and to all appearances the young plant becomes self-supporting. The latex throughout the aerial and underground stem now becomes milky and abundant, and is evidently at much greater pressure within the vessels, since, when a cut is made, a copious flow at once takes place from the region of the phloem. It is perhaps significant that the chlorophyll-lacking plants previously mentioned possessed very little latex, and that this was thinner and more watery than that of the normal plant. This, together with the fact that subterranean seedlings as a rule have no typical latex, suggests that the production of milky latex is in some way bound up with photosynthesis.

A frequent feature of the large seedlings which develop in heavy soil is that the aerial shoot is at first much more slender than the underground part (Text-figs. 26, 30). This is not so noticeable in the young plants which develop in light sandy soil. The length of time elapsing between the first appearance of the plant above ground and the opening of the first flower is entirely variable, as is also the length of the flowering season. Both depend directly on the position in which the plant is growing and to a smaller extent on its initial size before coming above the ground. Plants in favourable situations may take three or four weeks till flowering and continue flowering for a month or more. By "favourable" is meant a moderately shaded position, and moist cool soil. Exposed plants flower more quickly and for a shorter period.

Plants in full flower, which were dug up and brought into the laboratory and abundantly supplied with water, formed new roots to replace those which had been damaged. They continued to flower for 4 to 6 weeks and individual flowers remained open 7 to 10 days. Two plants which had finished flowering in the field, when brought into the laboratory, developed fresh lateral shoots and opened several flowers.

A large underground seedling usually ensures a fairly large mature plant even in dry situations; but of two plants which have an equal underground part, one in a favourable position will almost invariably give rise to a larger plant than one growing under more exposed conditions. On the other hand, a small underground seedling in an exposed situation usually means a small mature plant, sometimes only 5 or 6 cm. tall, with 4 or 5 small leaves and a single flower. But this is by no means the case in favourable positions. In this case quite a slender seedling may ultimately grow into a flourishing plant (see Text-fig. 25, in which the plant illustrated has a very short underground stem).

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In the case of dwarfed plants growing in unfavourable positions, it is practically always found that the root system commences to decay before flowering, but in the case of those in favourable situations, actively growing or at least living roots are always present until flowering has commenced, and often afterwards.

In *L. dentata* a method of vegetative reproduction was discovered which proved to be quite common. This was the production of shoots from buds developed on old roots. Text-figure 29 shows a fragment of the root system of a large plant and on it two young shoots have arisen. Text-figure 30 shows a relatively large plant arising adventitiously from a secondary root, quite close to the main plant, which in this case is still quite young.

Before or during flowering the root system and the base of the aerial shoot commence to die. Occasionally this is irregular so that isolated fragments of unwithered root occur between lengths of withered dead root. The decaying root system may become entirely isolated from the shoot, but often a plant can be excavated which shows the dying remnants of its root system still adhering to it. The above-ground parts of the plant represented in Text-figure 31 were practically dead, and most of the root system had decayed away, but two fragments of living root still remain attached to it. In several instances plants whose aerial shoots were quite dead and dry were excavated and in two cases such fragments, though withered at each end, had given rise to small healthy shoots (Text-fig. 32).

Lobelia gibbosa.—As a rule seedlings of *L. gibbosa* (Text-fig. 33) have shorter subterranean stems than do seedlings of *L. dentata*, but their root systems are equally extensive as compared with the size of the shoot. The young plant grows rapidly and at an early stage the aerial stem becomes fairly thick and succulent (Text-fig. 34), becoming more and more so until the inflorescence is produced. Text-figure 35, a plant just before flowering, shows the relatively great thickness of the stem as compared with that of *L. dentata* at a comparable stage of development (cf. Text-fig. 25). The stem begins to dry and die away from the root

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Text-fig. 26.—A young seedling of *L. dentata* from hard sandy clay showing increased diameter and crookedness of the shoot. S, shoot; R, root; L, rudimentary leaf. × 0·44.

Text-fig. 27.—A subterranean seedling of *L. dentata* from hard sandy clay showing twisted branching shoot. S, shoot; R, root; L, rudimentary leaf. × 0·7.

Text-fig. 28.—A subterranean seedling of *L. dentata* from hard sandy clay showing much twisted shoot. S, shoot; R, root; L, rudimentary leaf. × 0·7.

Text-fig. 29.—Young shoots of *L. dentata* arising adventitiously on the root system of a large plant. S, shoot; R, root. × 0·8.

Text-fig. 30.—A large branched plant of *L. dentata* from hard sandy clay soil showing a number of shoots (A) arising adventitiously from the one point on a lateral root (L.R.). S, shoot of the main plant; R, main root of the plant S; GL, ground level. × 0·6.

Text-fig. 31.—The lower part of the stem (S) of an old plant of *L. dentata* showing the decaying root system and fragments of living root (R). L, rudimentary leaf; A, axillary shoot. × 0·72.

Text-fig. 32.—An adventitious shoot (S) arising from an isolated piece of living root (R). × 0·44.

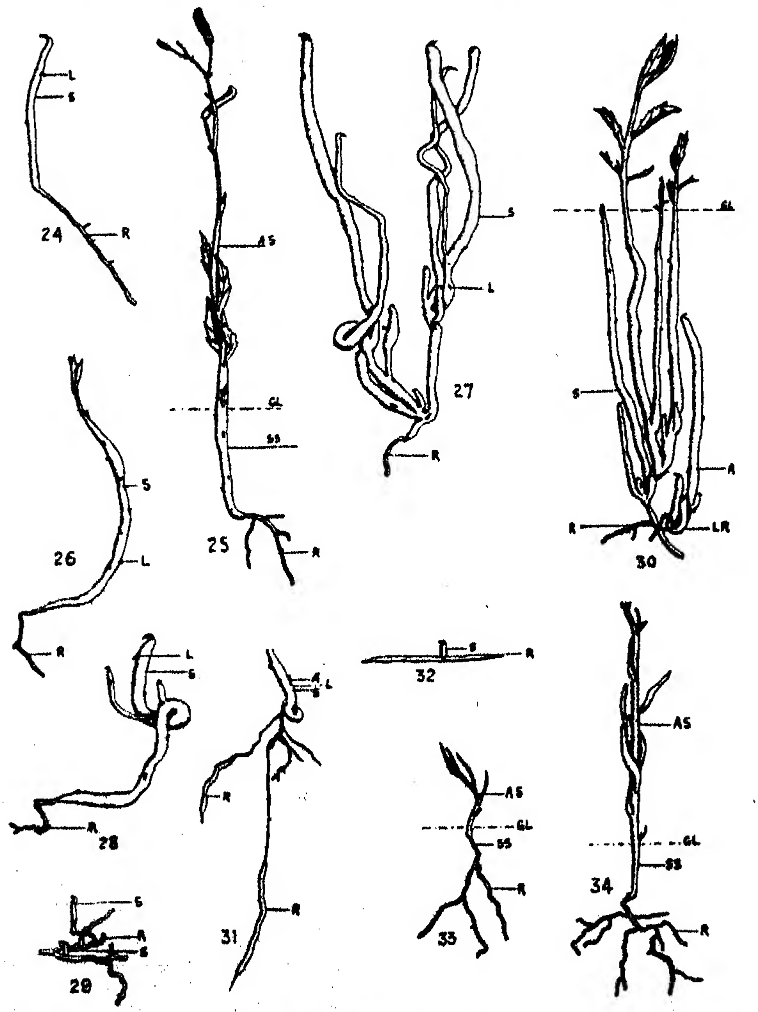
Text-fig. 33.—A young seedling of *L. gibbosa* showing the short length of the underground stem (SS). AS, aerial shoot; R, root; GL, ground level. × 0·4.

Text-fig. 34.—An older plant of *L. gibbosa* showing fleshy aerial stem. AS, aerial stem; SS, subterranean stem; R, root; GL, ground level. × 0·4.

upwards and the leaves wither about the time of flowering, and during the flowering period the aerial stem shrinks gradually in diameter (Text-fig. 36).

b. Internal Anatomy.

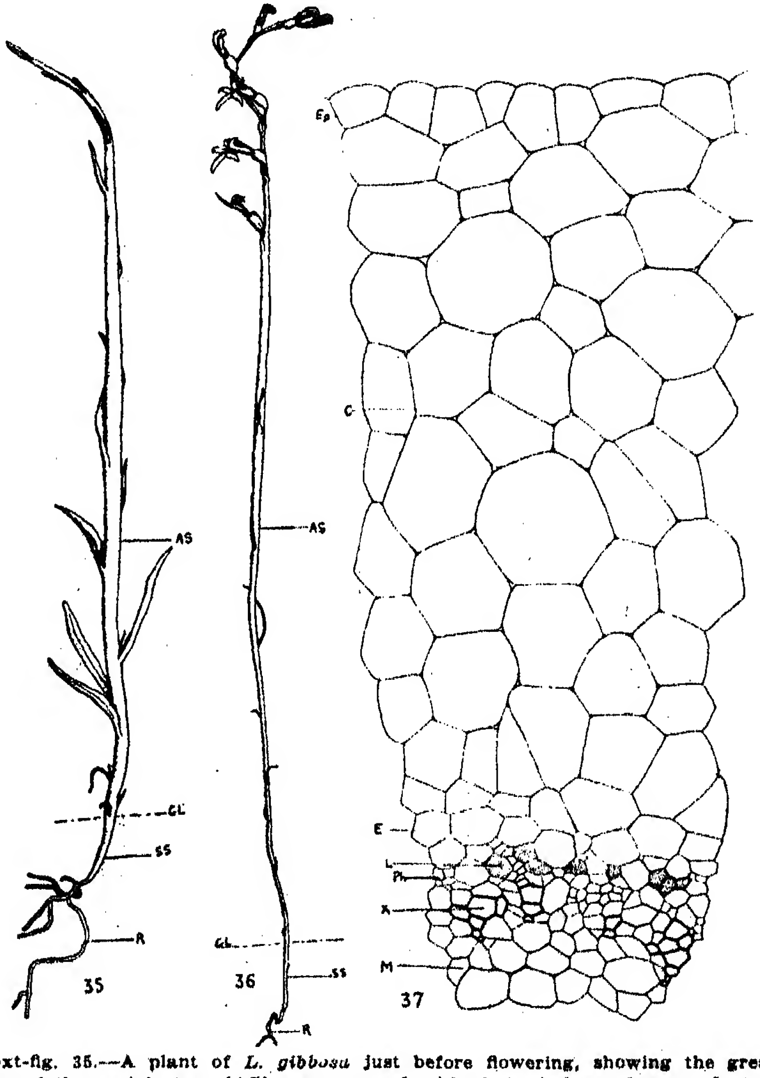
Lobelia dentata.—A transverse section of the shoot of a subterranean seedling shows the structure illustrated in Text-figure 37. The pith which is moderately wide and consists of large rounded cells, is not shown completely. It will be seen at once from an examination of the figure that the cortex (C) is unusually wide, and the cells are very turgid. There are usually a very large number of primary



Text-fig. 24.—A young subterranean seedling of *L. dentata* from light sandy soil. S, shoot; R, root; L, rudimentary leaf. × 0·48.

Text-fig. 25.—A young plant of *L. dentata* from light sandy soil showing the straight unbranched stem. AS, aerial stem; SS, subterranean stem; R, root; GL, ground level. × 0·4.

xylem groups (X) arranged fairly close together in a wide ring, and the phloem (Ph) forms a practically continuous ring outside them. Sieve tubes appear very small in transverse section, and in longitudinal section cannot always be distinguished from the parenchyma. Seedlings which develop in light sandy soil



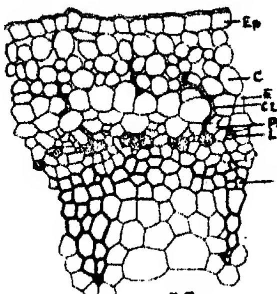
Text-fig. 35.—A plant of *L. gibbosa* just before flowering, showing the great size of the aerial stem (AS) as compared with that of the underground stem (SS). R, root; GL, ground level. × 0·4.

Text-fig. 36.—A flowering plant of *L. gibbosa* showing the withering of the root (R), and the lower part of the stem, and the leaves, and the decrease in thickness of the aerial stem (AS). SS, subterranean stem; GL, ground level. × 0·4.

Text-fig. 37.—Part of a transverse section of a very young underground stem of *L. dentata*. Ep, epidermis; C, cortex of large distended cells; E, endodermis; Ph, phloem; L, latex tubes; X, primary xylem; M, medulla. × 125.

may not have so wide a cortex as figured, but seedlings which develop in hard sandy clay often have an even wider one.

If sections are taken of the young aerial shoot of a seedling which has developed in heavy soil, the reason for the diminished diameter of its aerial stem is at once apparent. Text-figure 38 shows part of a transverse section of a fairly young aerial shoot; the width of the cortex is much less than in the underground stem, both in number and in size of cells, and becomes more so as we proceed upwards, but the diameter of the pith remains fairly constant. The



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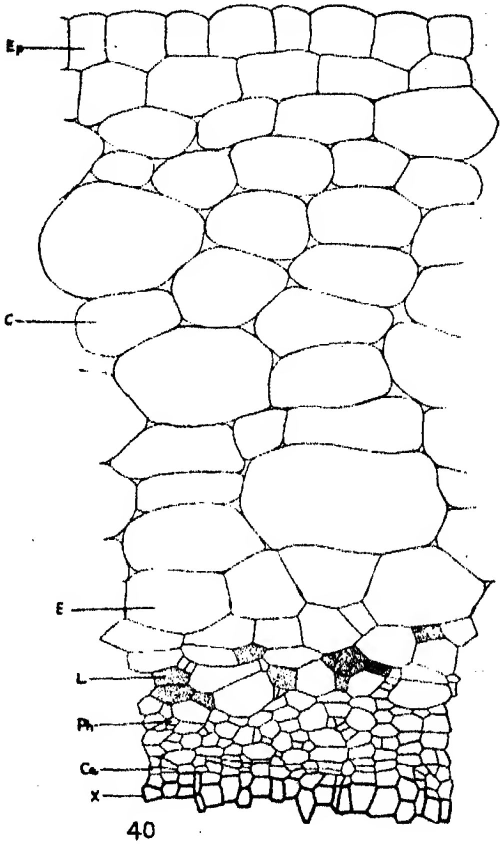

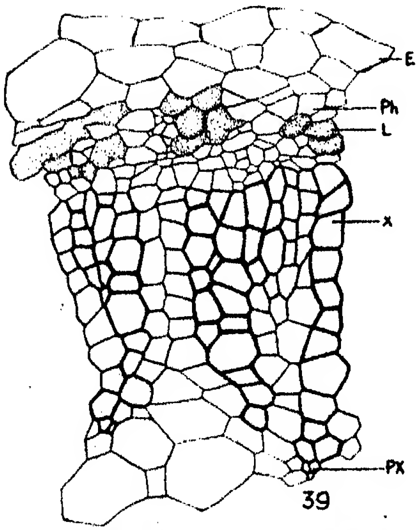

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Text-fig. 38.—Part of a transverse section of a young aerial stem of *L. dentata*. Ep, epidermis; C, cortex; E, endodermis; CL, latex tubes in the cortex; Ph, phloem; L, latex tubes in the phloem; X, xylem. × 150.

Text-fig. 39.—Part of a transverse section of a fairly old underground stem of *L. dentata* showing a small portion of the stele. E, endodermis; Ph, phloem; L, latex tubes; X, secondary xylem; PX, primary xylem. There is no sign of an active cambium, so that secondary growth has evidently ceased. × 150.

Text-fig. 40.—Part of a transverse section of the underground stem of a plant of *L. dentata* which has just begun to flower. Ep, epidermis; C, cortex; E, endodermis; L, latex tubes; Ph, phloem; Ca, cambium; X, secondary xylem. × 150.

activity of the cambium which commences very early in the aerial stem, spreading later to the subterranean parts, soon tends to equalise this difference of diameter. The greatest amount of secondary thickening takes place at the ground level, the amount of secondary xylem diminishing both upwards and downwards so that the stem usually tapers in both directions from the soil level (Text-fig. 25). Secondary xylem consists mainly of fibres and sclerized parenchyma with few vessels. There is little secondary phloem, but in the oldest stems the latex system may be much enlarged (Text-fig. 39).

The underground part of the stem up till the appearance of the first flower bud, or perhaps a little before, is almost transparent, and one can see the stele as a slender white strand in the centre. But with the commencement of secondary growth it becomes less and less so and is finally a uniform opaque white. This may be due to the great shrinking in diameter of the cortex, and to the increase in the amount of the latex. In Text-figure 40 is seen part of a transverse section of a fairly old underground stem which shows the commencement of this shrinkage of the cortex; this shrinkage is certainly not entirely due to the amount of secondary growth taking place in the stele, since at this time only a little secondary wood may have been added. It seems rather to be due to a loss of water from the cortex to the latex system, since, as was previously pointed out, if an old stem be cut across little fluid oozes out from the cortex, but a good flow of latex takes place from the phloem, whereas if a stem such as shown in Text-figure 27 be cut across very little sap oozes out from the phloem, most of it coming from the cut cells of the cortex.

The anatomy of the root and underground stem of *L. gibbosa* is not sufficiently different from that of *L. dentata* to need a separate description. The main difference is in the aerial stem, which, as we have seen, is much thicker and more succulent than in *L. dentata*. A section of a young stem at about the stage shown in Text-figure 32 shows that the reason for this is that the cortex is very wide, wider even than it is in the subterranean part of the stem. Text-figure 41 is part of a transverse section taken in this region, and it can be seen at once that the cells of the cortex are very large and turgid and resemble rather the cells of the cortex of the young subterranean stem of *L. dentata* than those of the young aerial stem.

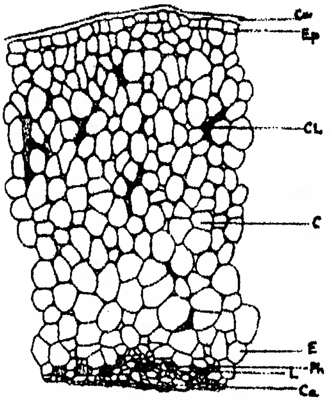
The Latex System.

The latex system is similar in both species, and will only be briefly described, since Ydrac (1905) has given a fairly full description of the latex system of the Lobelias. Ydrac found that there were two kinds of latex tubes in this genus: (1) The main latex vessels in the phloem, which run more or less vertically and result from the breaking down of end walls between superimposed rows of cells, and are therefore true latex vessels, and (2) branches which originate as outgrowths of these, and form connecting links between the vessels, and also ramify in a winding fashion through the cortex.

There is no essential difference in the latex system of the two species under discussion and that described for the Lobelias by Ydrac, save that there were no latex vessels developed in the pith or xylem at any place. One point noticed by Ydrac is especially conspicuous in these two species: this is that the latex tubes are confined to the phloem in the root and the underground part of the

stem, but in the aerial stem branches ramify through the cortex, first having *forced their way out from the stele between the cells of the endodermis.*

As we have already seen, latex vessels develop early in the young root (Text-fig. 19), and are at first small and few in number; they later enlarge considerably and branch so that a fairly extensive network is formed. When secondary thickening occurs new phloem elements are added, and some of these become latex vessels and link up with the primary latex vessels by means of outgrowths of their



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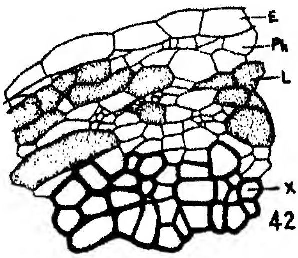
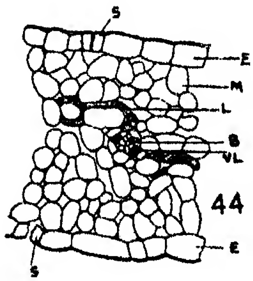
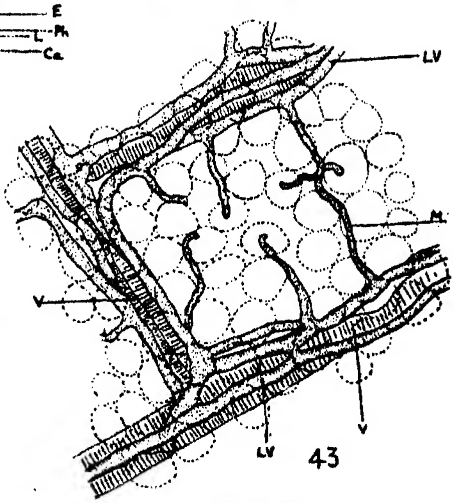






Text-fig. 41.—Part of a transverse section of a young aerial stem of *L. gibbosa.* Cu, cuticle; Ep, epidermis; C, cortex; CL, cortical latex tubes; E, endodermis; L, latex tubes in the phloem; Ph, phloem; Ca, cambium. × 52.

Text-fig. 42.—Part of a transverse section of an old main root of *L. dentata* showing portion of the stele. E, endodermis somewhat stretched by the formation of secondary xylem; Ph, phloem; L, latex tubes which have increased considerably in size and number (cf. Text-fig. 19); X, secondary xylem. × 150.

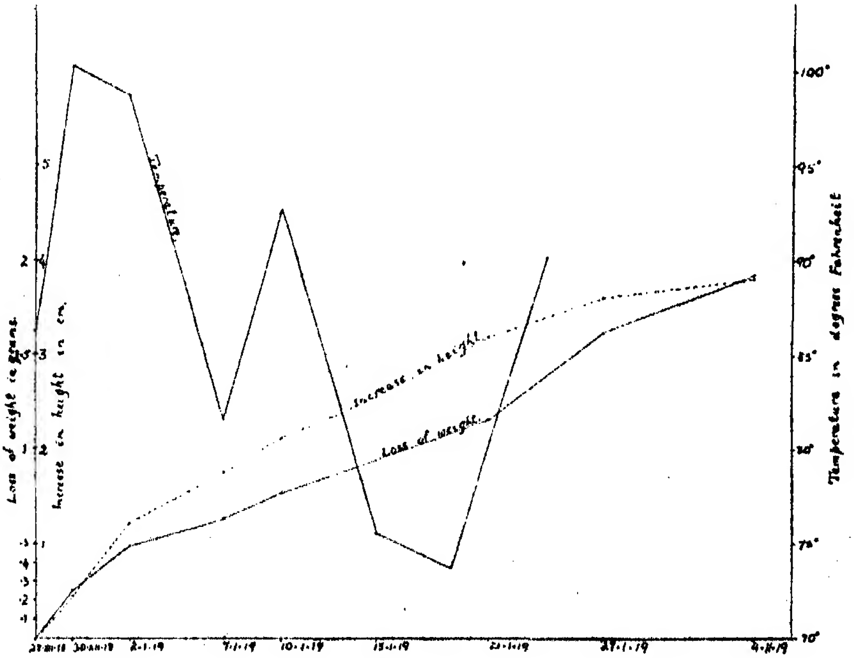
Text-fig. 43.—Surface view of part of a leaf of *L. dentata* as seen after soaking in 5% caustic potash for five days, showing the course of the latex tubes in the mesophyll. V, veins; LV, latex tubes accompanying the veins; M, short branches of the latex tubes which ramify through the mesophyll. × 150.

Text-fig. 44.—Part of a transverse section of a young leaf of *L. dentata.* S, stomate; E, epidermis; M, mesophyll; B, vascular bundle; VL, latex tubes accompanying the vascular bundle; L, latex tubes in the mesophyll. × 150.

walls. Text-figure 42 shows part of a transverse section of an old root; when this is compared with Text-figure 19, it is evident that the latex system has enlarged very considerably. Similarly in the young stem (Text-figure 37) the latex tubes are small and not very numerous, but in a section of an older stem they are much enlarged (Text-fig. 39). In transverse sections of the aerial stems of both *L. dentata* (Text-fig. 38) and *L. gibbosa* (Text-fig. 41) the latex cells can be seen ramifying through the cortex. They are also abundantly present in the leaf, several vessels accompanying each vein, and giving rise to branches which follow a sinuous course through the mesophyll (Text-figs. 43, 44). Latex vessels are also present in all parts of the flower.

General Biology, Experiments and Observations.

Experiments were made by Miss Rennie during the summers of 1917–18 and 1918–19 on the growth of shoots of *L. gibbosa* when dug up and allowed to dry. Measurements were made at intervals of the length of the plants from a marked point on the stem to the apex, and each plant was weighed. Comparable results were obtained in both cases. The data obtained from the 1918–19 experiment are combined in the accompanying graph.



Graph showing loss of weight and increase in height. Average loss of weight (5 plants) 1·17 grm. in 38 days; max. loss 1·93 grm.; min. loss 0·75 grm. Average increase in height (5 plants) 3·85 cm. in 38 days; max. increase 6·4 cm.; min. increase 2·8 cm.

Five plants were weighed and measured and the results averaged. The curves representing increase in height and loss in weight are very similar; the loss in weight is at first fairly sharp and then becomes less, rising again towards the end of the experiment. After an initial spurt, increase in height became gradually less till it ceased with the opening of the last bud at the end of the experiment.

There is no evidence that either loss of weight or increase in height was influenced, during this period, to any marked extent by the external environment, since, while the experiment was in progress, there was a period of heat with a maximum shade temperature of 106·8° on 5th January and two spells of fairly cool weather, which caused no noticeable variation.

In contrast to this behaviour, plants of *L. dentata* were found to wilt in two or three days if the soil in which they were growing were allowed to dry out, and plants which were dug up and allowed to dry wilted and died at once. Even plants with large underground stems could not withstand a much longer period of dryness.

The reserve food in the fungus in growing roots.—The droplets of reserve food in the fungal hyphae during the fungal enlargement period and the droplets which appear in the cortical cells of the root during the subsequent period of fungal depletion stained at first dark brown with 1% osmic acid. When hand sections so stained were mounted in glycerine jelly, in a few days the brown colour diffused out from the sections leaving the droplets stained a dense black. In material which was fixed in Flemming's fixative and embedded in paraffin, the droplets appear black, the brown staining material having evidently been washed out, probably in alcohol. This reserve food is entirely soluble in chloroform, and stains in Sudan III, and in sections of fresh material, collects in droplets around the section. It is probably an oily material, mixed with a diffusible alcohol-soluble proteinaceous substance.

Reserve food in the subterranean stem of L. dentata.—Positive tests for sugar in the cortex of subterranean seedlings of *L. dentata* were obtained by the alpha naphthol test, and by Mayer's method (Haas and Hill, 1928). The Osazone test (Mangham, 1915) showed more clearly in which part the sugars were most abundant, and also gave some indication of the type of sugar involved. In very young stems the sugar is distributed throughout the cortex fairly evenly. In about six weeks after treatment of sections of young stems by this method the sugar commences to crystallize in large clusters from droplets of a golden-brown liquid, and from the shape of the crystals and their manner of formation it is probable that the sugar involved is maltose.

In older stems, the sugars become restricted to the middle and inner cortex, and at the same time become abundant in the latex. In still older stems no sign of sugars can be found in the cortex, and they finally become much less abundant in the latex also.

The staining reactions of the latex with 1% osmic acid and with potassium iodide-iodine suggest the presence of oily and proteinaceous substances but no starch. Partial solubility of the latex in 5% alcoholic solution of tartaric acid (Haas and Hill, 1928) suggests the presence of an alkaloid.

Discussion.

a. Germination and the Young Seedling.

The seed before germination is packed with oil, but even so, so small a seed could not give rise to a very large seedling unaided by photosynthesis or some other means, and, as we saw, a relatively enormous subterranean seedling develops from it. It seems, therefore, undoubted that the fungus which is invariably associated with the seedling must provide the necessary food for such growth, and that we must regard *Lobelia dentata* and *Lobelia gibbosa* as holoparasites on the fungus, at least in the subterranean stage of their growth.

The following is a description of what is believed to occur in germination. It has been deduced from an examination of fairly large seedlings, and must be confirmed by experiment before it can be entirely accepted. The embryo starts to grow at the expense of the endosperm, producing a small, probably undifferentiated, protocorm-like structure; the testa becomes thrown off and the endosperm cells remain for a time as broken fragments on the outside. This is a critical period and probably the time when most loss of life occurs. The plant has used up all its reserve food and is still far below the surface of the soil, with no chance of becoming self-supporting. It is therefore imperative that an association with the fungus should take place. This appears to come about as follows: in the soil there are present rhizomorph-like strands of fungal hyphae; one of these grows into contact with a young *Lobelia* embryo, the strand spreads out over the surface of the embryo, forming a practically continuous mat several cells deep; it is evidently attracted there by some chemical substance. Wedges of mycelium are pushed in between the epidermal cells and into the cortex, remaining, however, strictly intercellular. The young plant is able to extract carbohydrate and nitrogenous food from the fungus, and enlarges rapidly so that the cells of the cortex become much stretched tangentially. A shoot then grows upwards bearing rudimentary leaves, and a root grows downwards, which is from the beginning infected by the fungus.

It seems rather extraordinary that germination should as a rule take place so far below the surface of the soil. Such small seeds, however, might be fairly easily washed down into crevices and covered up; a rather favourite place for germination is in accumulations of soil washed up against rocks or the bases of tree trunks in which seeds could readily become buried. Possibly also, the fungus necessary for germination is not present in the upper layers of the soil.

The form of seedlings which commence growth in heavy soil can probably be ascribed to the physical conditions of their surroundings. Such seedlings would naturally find a greater barrier to their upward growth than seedlings growing in light sandy soil. It is therefore reasonable to expect that they would take longer to reach the surface, and so there would be a longer period for food to accumulate in them. This would account for their large size and might possibly induce the formation of branches. Especially hard patches in the soil or fragments of stone would cause the seedling to become twisted.

b. Mycorrhiza.

A number of interesting points in connection with the mycorrhiza have emerged during the investigation of *L. gibbosa* and *L. dentata*.

It appears to be the first instance noted of the obligate association of an annual herb with a mycorrhizal fungus, though obligate associations of annual parasitic plants with their hosts are not uncommon. It is considered justifiable

to regard these two species of *Lobelia* as obligate parasites on the fungus, because germination invariably takes place at such depths below the surface of the soil as to make it impossible for the young seedling to become self-supporting at once, and because all root systems examined showed the presence of the fungus.

A comparison of this type of mycorrhiza with other known types (Rayner, 1927) makes it evident that it cannot be grouped satisfactorily with any of them. First we have a two-phase mycorrhiza in *Lobelia*; the root system of a plant is infected from the beginning of its growth by the fungus which invades the hypocotyl, this fungus keeping pace with the growing root by invading the newly-formed tissues; it then builds up a reserve of food material within its cells and later loses this to the cells of the cortex of the root; but the root system is also subject to more or less numerous local reinfections from the soil by isolated rhizomorphs of the same fungus.

Secondly, the behaviour of both sets of mycelium within the root is unusual in that the hyphae are at all times strictly intercellular. Thirdly, the mechanism of extraction of food materials by an intercellular mycelium from the cells between which it grows is extraordinary in a mycorrhiza, and rare even in fungal parasites of higher plants. The ensuing extraction of food from the fungus by the cells of the cortex is no less unusual. It seems to be due to changes in relative permeability on the part of the cells of both the mycelium and the root cortex. In the first place food material accumulates in the hyphae, some of it possibly at the expense of the root. Subsequently these food materials disappear from the fungus and at the same time reappear as minute drops in the peripheral cytoplasm of the neighbouring cortical cells. The osmotic exchanges involved must take place through two sets of semipermeable membranes and the adjacent cell walls, those of the fungus and the cortical cells. But the nature of the changes which take place in the cells of these two organisms is not known, nor even the condition in which the food stuffs are transferred.

There is not a great deal of similarity between ectotrophic mycorrhiza and the mycorrhiza of *Lobelia*. Ectotrophic fungi, though mainly intercellular, are occasionally intracellular; they are usually limited to the outer cortex of the root and the mycelium forms a thick mat over the surface of the root and penetrates into it at all points; whereas in the case of the *Lobelia* mycorrhiza, each rhizomorph has a single point of entry into the root, and the mycelium penetrates throughout the cortex.

There is even less in common between the *Lobelia* mycorrhiza and the endotrophic types which produce "arbuscules", for in this case also the arbuscules are intracellular and become digested by the cells they invade.

In the case of the orchid mycorrhiza also the behaviour of the fungus within the plant has no similarity to that of the *Lobelia* mycorrhiza. In the orchid the fungus is entirely intracellular and forms clumps of hyphae within the cells and these are digested later by the higher plant.

There is some similarity between the germination of orchid seeds and what is believed to be the case in *Lobelia*. In both cases fungal infection comes from the soil, in orchids it is obligate except under artificial conditions, and in *Lobelia* successful germination in the field seems undoubtedly to depend on fungal infection. Whether the similarity is more than superficial cannot be determined until *Lobelia* seedlings have been cultivated under controlled laboratory conditions. It has been shown that some orchids are entirely free of mycorrhizal fungus in the adult condition and that they evidently behave as autotrophic plants. For *Lobelia*

also there is evidence that, once able to conduct photosynthesis, the plant, if favourably situated, can support itself.

The invasion of roots of *L. gibbosa* and *L. dentata* by separate strands of fungal hyphae finds its nearest comparison in the mycorrhiza of the orchid *Gastrodia elata*, which is described by Kusano (1911) as forming an obligate association with the rhizomorphs of the fungus *Armillaria mellea*, but the likeness ceases with the external appearance, since *Armillaria* commences by making a parasitic attack which is countered by the orchid, and its hyphae become intracellular and are ultimately digested by the cells of the orchid.

It may be of some importance that the nuclei of the cells of the cortex of the root of *Lobelia* never at any stage become enlarged and distorted as is commonly the case in the development of other mycorrhizal associations.

It must be admitted that the method of nutrition of *L. gibbosa* and *L. dentata* is not yet fully elucidated, nor can it be until plants can be grown from seed under controlled conditions.

Without evidence to the contrary it seems as if the subterranean seedling must rely for its entire food supply on those fungal strands from the soil which make connections with its roots, since the hyphae which grow down from the hypocotyl within the root have no direct connection with the outside medium. But a careful examination of numerous roots showed that though the external strands were occasionally very abundant, they were often very infrequent. Though they may be present in sufficient numbers to supply the growing plant with all its food requirements, it is not considered justifiable to assume that this is always the case. The function of the fungus which develops within the root is at present obscure. It is possible that it may utilize soluble organic substances absorbed in the soil solution by the root, and convert these into a material which is available to the plant. Unless this is the case, this phase of the fungus, once the seed has germinated, seems to be of the nature of a parasite which is kept in check by the higher plant.

c. Latex System.

Latex systems of plants have been classified according to their origin into two groups, latex cells which grow through the plant body after the manner of fungal cells and are non-septate throughout their length, and latex vessels which result from the breaking down of end walls between superimposed rows of cells. In *Lobelia* the latex system combines features of both types, the main latex tubes in the phloem belong to the second category, but the irregular anastomoses, and the ramifying branches in the cortex are almost certainly due to outgrowths of parts of the walls of the main latex vessels, and therefore come into the first class. This is also probably the case for the finer tubes in the mesophyll of the leaf, whereas the main latex tubes of the leaf which accompany the veins, not infrequently show traces of transverse walls in sections of very young leaves.

The function of the latex system in the roots and stem seems to be undoubtedly that of conduction; in support of this there is the fact that as the fungus at the root tips becomes depleted, the latex tubes become filled with food material. Also, in the underground stem, sugar gradually disappears from the cortex and at the same time the latex becomes more and more abundant. Both in the root and in the stem the number and size of the sieve tubes are very insignificant. It seems also to be important that the chlorophyll bearing tissue of both stem and leaves

is intersected and tapped by latex tubes very abundantly; here it seems very likely that the latex tubes serve to carry away the products of photosynthesis.

d. General Biology.

Whilst the seedlings of *Lobelia* are subterranean, there is no doubt that they are wholly dependent on the fungus associated with their roots, both for nitrogenous and carbohydrate foods; but as soon as the plant comes above ground it is at least partly self-supporting, since it develops an abundance of chlorophyll and occasional thin absorbing roots.

Though the method of nutrition of the two species is fundamentally the same, there are important differences in their behaviour. *L. gibbosa* has been shown to behave as a succulent in that it continues to grow in length and open flowers, at the same time slowly losing weight, even when removed from the soil and supplied with no water. *L. dentata*, on the other hand, is a much less robust plant, and in spite of the fact that it frequently has a great length of subterranean stem, which in the young plant may contain considerable quantities of water, this species has none of the characteristics of a succulent.

In the case of *L. dentata*, though the development of an aerial shoot is of advantage in that it ensures a more reliable source of food, it introduces a danger to which the subterranean seedling was not subjected, namely, that of transpiration. It is very evident that *L. dentata* is unable to cope with conditions of rapid transpiration; plants growing in open sunny situations are practically always much dwarfed as compared with shaded plants. This is very probably the direct result of the structure of their root system, which even a superficial examination will show to be eminently unsuited for rapid water absorption, being devoid of root hairs and composed of roots which are too thick to form close contact with soil particles. This explains why plants of *L. dentata* show symptoms of water shortage in positions where other plants, whose root systems are more efficient in the absorption of water, can flourish. It also explains why dwarfed plants whose flowering period was over, when transplanted into pots and abundantly supplied with water, develop fresh lateral shoots and new roots.

Summary.

Lobelia gibbosa and *Lobelia dentata* are annual herbaceous plants whose manner of growth shows several points of interest.

L. gibbosa is widely distributed throughout Australia. Its average height is about 47 cm., but specimens growing in exposed positions are usually much shorter. The above-ground stem is succulent. At the time of flowering the root and underground part of the stem and the lower leaves are withering or dead, the plant evidently living on the stored materials in the stem.

L. dentata is limited to the coast and adjacent highlands of New South Wales and southern Queensland. It is on the whole a smaller and less robust plant than *L. gibbosa*, and its aerial stem is not succulent. The underground part of the stem may be 15 cm. or more long, in contrast with *L. gibbosa*, whose underground stem averages about 5 cm. in length. When the plant is young the cortex of the subterranean part of the stem is wide and succulent and a good deal of sugar is present. As the plant increases in size the sugar becomes transferred to the latex vessels and transported away, and the cortex shrinks, evidently losing

water as well as sugar. As is the case with *L. gibbosa*, plants growing in exposed positions are much smaller than more favoured plants.

In both species germination usually takes place at a distance below the surface of the soil, and at first the seedling is entirely subterranean. Successful germination, therefore, depends on an early infection by a fungus, since the seeds are very small and do not contain sufficient reserve food material to provide for much growth.

Strands of fungal hyphae are always found associated with the hypocotyl region of young seedlings; they spread out forming a mat over its surface and in places penetrate into the cortex by pushing down between the epidermal cells. In the cortex they remain strictly intercellular, and in transverse section are seen to be most abundant in the outer cortex, probably because the hyphae which penetrate into the inner cortex are quickly crushed out. This intercellular fungus evidently infects the young primary root as soon as it commences growth, and keeps pace with it as it grows, also infecting all lateral roots and their branches.

The apex of a young growing root is free from fungal hyphae. Behind this area three stages in the association of the fungus and the cells of the root can be distinguished:

1. *The period of fungal invasion.*—In a longitudinal section near to the apex of a young growing root, the invading hyphae can be seen growing down between the cortical cells, and are evenly distributed throughout the whole cortex. At this time the fungal hypae are narrow and densely protoplasmic.

2. *The period of fungal enlargement.*—Sections taken successively further and further from the apex of a young growing root show that the fungus becomes concentrated in the middle cortex forming a definite fungal zone. In this region the fungal cells become much enlarged by the accumulation of droplets of reserve food of an oily nature within them, and the cortical cells become forced apart. The fungal hyphae in the inner and outer cortex are not only less numerous, but also thinner and contain less reserve food.

3. *The period of fungal depletion.*—Sections cut behind the region showing fungal enlargement show that changes take place in the fungal zone resulting in the disappearance of all reserve food from the fungal hyphae and the accumulation in the peripheral cytoplasm of the neighbouring cells of very numerous small droplets of reserve food with similar staining reaction. The depletion of the fungus commences in the inner fungal zone and continues outward until there is no reserve food remaining in the fungus. During this period the cells of the outer cortex increase in size, gradually crushing the fungus till none remains except a few living threads in the outer cortex. Food material is evidently extracted by the fungus from the cortical cells and later by the cortical cells from the fungus by osmosis, since no signs of haustorial organs could be found. As the food material is extracted from the fungus it is transported across the cortex to the latex vessels and thence to the growing stem.

Strands of fungal hyphae similar to those associated with the hypocotyl of seedlings are also found associated with the roots. The outer part of the strand consists of a number of narrow thick-walled hyphae, somewhat intertwined but with a general longitudinal course. These are closely bound together so as to form a continuous tissue protecting the core of the strand which consists of one or more wide, thin-walled, densely protoplasmic hyphae, whose course is strictly longitudinal.

Where these strands grow into contact with a root of *Lobelia* the outer layer spreads out over the surface forming a mat which may be extensive or very narrow. From the core a strand of hyphae grows down into the cortex of the root, penetrating between the epidermal cells and growing through the intercellular spaces of the cortex.

The main points of importance of the latex system are described. In the roots and underground stem the latex system is confined to the phloem and consists of large vessels with numerous anastomosing branches. The vessels result from the breaking down of end walls between rows of superimposed cells, and the branches are probably prolongations of the cell wall. In the aerial stem the main part of the latex is in the phloem, and is similar to that of the underground stem, but a characteristic feature is that branches grow out from the main vessels, and penetrate between the cells of the endodermis and ramify between the chlorophyll-bearing cells composing the cortex. In the leaf several latex vessels accompany each vein and numerous branches grow out between the mesophyll cells. Latex vessels are also present in all parts of the flower. It is concluded that in *L. gibbosa* and *L. dentata* the latex system functions mainly in transport of food materials.

L. gibbosa behaves as a succulent when deprived of water, but *L. dentata* under similar conditions dies at once in spite of the considerable development of the cortex in the underground stem, which in the young plant contains much water.

From its general structure the root system of the two species appears to be an inefficient organ for the rapid absorption of water, and it is for this reason that plants in fairly exposed situations do not flourish, though other plants whose root systems are not modified, grow well and show no signs of water shortage under the same conditions.

In conclusion the author wishes to express her thanks to Professor T. G. B. Osborn of the Department of Botany, Sydney University, who suggested the problem, for his helpful criticism and advice.

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FLETCHER MEMORIAL LECTURE, 1931.

THE ANIMAL MIND AND ITS SIGNIFICANCE FOR BIOLOGY.

By W. E. Agar, F.R.S.,
University of Melbourne.

[Delivered 9th November, 1931.]

It cannot be denied that some explanation is required of a biologist who chooses as a subject for a lecture a theme which could, from nearly every point of view, clearly be treated better by a professional psychologist than by a biologist. Nevertheless, granting this, as we certainly must, there still seems room for its treatment by a biologist to biologists, and, therefore, it is, perhaps, not an unsuitable subject for me to choose for your Fletcher Memorial Lecture, which you have done me the honour of inviting me to deliver this year.

The history of science shows two opposite tendencies. Including at first the whole range of nature, natural science in the not so distant past was thought to be a proper subject for a University Chair. But the mere growth of knowledge made it necessary to subdivide the field for purposes of practical study. Later still, as knowledge increases still further, the boundaries of these subdivisions spread out till they overlap again, and regions are established which have to use the discoveries and concepts of different branches of scientific discipline. Of recent years the region common to physics and chemistry has been very prominent. The common ground of biology and chemistry has grown enormously in the last generation. The contact between zoology and psychology is less well established. The fact that the vital processes, such as morphogenesis, or physiological regulation, have a physico-chemical aspect has been thoroughly appreciated for many years; that they may have a psychical aspect will be much less universally admitted, though it may be equally true.

There is another aspect of animal psychology, however, in which every biologist is bound to be professionally interested, and that is the evolutionary aspect. His conception of organic evolution is obviously incomplete if he ignores the evolution of mind. He will be lucky indeed if he arrives at a correct conception of the process and course of evolution if all consideration of the evolution of the most characteristic of all animal functions is left out of the picture.

It is convenient to begin by distinguishing the two main subdivisions of animal behaviour recognized by nearly all animal psychologists. Firstly, there is that type of behaviour which is determined by the innate organization of the animal, that is to say, reflex and instinctive behaviour. This type of behaviour is the outcome of the organization of the animal as this has been developed by the ordinary processes of embryonic development, often with post-embryonic maturation (as in the case of the sex instinct).

Secondly, we must recognize that type of behaviour which is determined by the animal's own previous experience; actions which the animal has learnt by

experience to be appropriate to certain situations. This type of behaviour is intelligent behaviour. The bird builds its nest instinctively; a dog recognizes intelligently that the sound of the dinner bell means food.

Let us consider briefly the nature and relations of these two types of behaviour. Instincts are sometimes looked upon as compound reflexes, but McDougall has stressed the necessity for distinguishing sharply between these two modes of action. A reflex action is a reaction to a stimulus as such, without reference to the source of the stimulus. Instinctive action, however, is a reaction not merely to the stimulus itself, but to the object or situation which the stimulus means or signifies to the animal. Flash a bright light on to a dog's eye. It will blink—a reflex action to the stimulus itself. But if the image of a rabbit falls upon its retina, it will react, not merely to the stimulus of the optic nerve, but to the rabbit, which the stimulus signifies to the animal.

Thus, while the reflex act merely involves the touching off of a preformed mechanism, like putting a penny in an automatic machine, an instinctive act involves a striving towards a goal. Instinctive action, therefore, implies cognition and conation. Moreover, as McDougall also points out, the same instinctive action may employ different motor mechanisms on different occasions.

We know from our own experience that reflex action is not usually a conscious action. Instinctive action, on the other hand, is accompanied in our own case, and, therefore, presumably in the case of animals, by conscious experience of the type called emotion, according to McDougall's terminology. The operation of the instinct of escape is accompanied by the emotion of fear, and so on.

It seems clear that in order to be effective, only the simplest instinctive actions can be absolutely determined in every detail by the organization of the animal. Only the impulse to the action and the general course of the action can be thus determined, because the exact situation and, therefore, the exact means to be taken to attain the goal, can hardly ever be the same on any two occasions. Of course, the animal is guided in its movements by its sense organs, and by this means no doubt the spider is able to fix its web to the appropriate supports and shape the whole to the space at its disposal. The power to do that is included in the definition of the instinct. But animals in the performance of their instinctive acts are bound to come up against all sorts of minor obstacles, the appropriate way of dealing with which could not be part of the instinctive equipment of the animal, unless this included an enormous number of latent specific cognitive and conative dispositions which might not need to be brought into operation once in scores of generations. The way in which the details of the action can be suited to the minor features of the special case is a very simple one, but very important for the understanding of animal behaviour, and of mental evolution. It is the principle of trial and error.

It appears to be a fundamental attribute of animals to vary their previous activity (or inactivity) when they come into any situation which causes them pain or dissatisfaction—and this situation arises automatically when any animal receives a check when making for its instinctive goal. When this happens, the animal continues to make movements of the same general nature as those usually appropriate to attain the goal, but varies them in detail. Movements which fail to give it relief (in the case of the checked instinctive action, to bring it nearer its goal) are discontinued and others substituted, until one is found which

gives the animal satisfaction; the stimulus to further change of activity no longer exists, and the present movement or state of rest is continued.

Thus it is that motile microscopic organisms, such as *Paramecium*, placed in a trough of water, one end of which is kept at an uncomfortably high temperature and the other end at normal temperature, will eventually congregate in the cool end. The uncomfortably high temperature causes them to dart about at random; those directions of movement which fail to give relief—i.e., fail to take the animal out of reach of the heat—are quickly discontinued, and the animal turns in a new direction. Sooner or later, it chances to move in a direction which takes it out of the hot area into the cool. There being now no incentive to further activity, the animal stays where it is. In this way, the animals gradually all find their way to the cool end.

There is nothing unfamiliar to us in this procedure. As long as we ourselves are comfortably situated, we feel no incentive to alter our condition, but when we experience discomfort or pain we get restless and try various ways of obtaining relief.

It is even possible to relate the frequency of change of action with the degree of discomfort or pain which evokes it. In one of my own experiments, water mites (*Eylais*) were placed in a horizontal glass tube about 60 cm. long, so arranged that it could be maintained at a constant temperature. In such a tube the animal swims up and down, sometimes reversing its direction after a short distance, sometimes after a long one. Each animal was left in the tube for an hour, and its track up and down the tube recorded. The average length of run between reversals of direction was as follows (compulsory turns at the ends of the tube not being counted). At a temperature of 6·5° C., the average run was 747 mm.; at 12·5°, 1,932 mm.; at 22·5°, 1,761 mm.; at 32°, 460 mm.; and at 37°, 72 mm.

It will be seen that at the "normal" temperatures, 12·5° and 22·5°, the reversals of direction are at much longer intervals than at higher or lower temperatures; and, indeed, one is led to the generalization that the rate of change of action is roughly proportional to the degree of injury and discomfort experienced during its performance. This seems to be the basis of the principle of trial and error.

This trial and error principle is the essential preliminary to intelligent behaviour. No intelligence is involved in the Paramecium's behaviour. That would appear if, in a second experiment with the same animals, their previous experience led them to turn away from the hot end and swim into the cool end of the trough, instead of chancing on the cool end by random movements—and we may be confident that this intelligence would not be displayed.

As an example of intelligence in this sense of learning by trial and error, let us take one of the earliest—if not the earliest—exact experiment on this subject.

Thorndike put a hungry cat in a cage, food being placed outside. The cage was provided with a sliding door to which was attached a string passing over a pulley and ending in a weight. The door was kept shut by a bolt, the withdrawal of which allowed the door to rise. To the bolt was fastened a string which, passing over a pulley and through the bars of the roof, ended in a ring hanging in the middle of the cage. Pulling on the ring would, therefore, cause the door to open.

The cat on being put into the cage tries to escape by biting and clawing at the bars and attempting to squeeze between them. Sooner or later it chances

to claw or bite on the ring; it then finds itself at liberty. On successive occasions the cat gradually eliminates more and more of the preliminary useless efforts, and concentrates on the essential act of pulling the ring. One particular cat took the following times (in seconds) to pull the ring, and so gain its liberty, in twenty-four successive trials: 160, 30, 90, 60, 15, 28, 20, 30, 22, 11, 15, 20, 12, 10, 14, 10, 8, 8, 5, 10, 8, 6, 6, 7.

Biting the ring or pulling on it with its claw is, no doubt, an act of the general kind which a cat instinctively uses in efforts to escape from confinement. But animals will also learn to perform acts which can have no understandable relation to the result. For instance, in other experiments Thorndike opened the cage door himself whenever the cats licked themselves, and they soon learnt to do this immediately they were put into the cage. Similarly, a chicken learnt to free itself by preening its feathers.

The power of learning by experience (and, therefore, according to definition, intelligence) has been demonstrated in all classes of vertebrates and in many invertebrate phyla.

Passing over certain equivocal evidence in the case of the Protozoa, and fairly strong evidence for the earthworm (Yerkes), Garth and Mitchell (1926) may be said to have proved it in the case of a land snail. The enormous and specialized phylum of the Arthropoda has been much experimented upon from this point of view. In this phylum my own experiments (1927) have failed to produce any evidence of intelligence in water mites (Hydrachnidae). The apparatus employed was a Y-shaped trough, supported on a pedestal in a dish containing water. The depth of the water in the dish was so adjusted that the trough contained only sufficient water to allow the animal to struggle along in it, half swimming, half crawling. The animal was introduced into the base of the stem of the Y; by the right hand arm it could escape into the deep surrounding water; escape from the left arm was prevented by a piece of clear glass. In one out of many experiments, in which the penalty for entering the wrong arm was not only failure to escape from the confinement and shallow water, but also the reception of an electric shock, the animal failed to show any signs of learning even after 800 trials.

This inability to learn a simple right or left hand choice is in marked contrast to the powers of another Arthropod, the freshwater crayfish, which will master this task very easily. It seems possible to correlate this difference of intelligence with the modes of life of the two creatures. The crayfish leads a life where some power of profiting by experience must clearly be of value—it searches for its food, attacks other animals, and defends itself against its enemies.

Water mites feed on *Daphnia* or other small Crustacea, but they catch them in a manner which affords no apparent scope for intelligence. They are animals of ceaseless activity, swimming rapidly round and round, up and down the vessel in which they are contained. If a water mite (*Eylais*) is placed in a small vessel with a few Daphnias, it seems quite unconscious of their presence, even at a distance of a millimetre. But when in its tireless travelling it chances to collide with one, it makes a rapid movement to seize its prey. If successful, the Daphnia is killed and its juice is sucked; if the mite fails to hold the Daphnia it circles once or twice round the spot and by so doing may strike the Daphnia again. If not, it soon resumes its general random activity. That mites find their prey by chance collisions with them is also indicated by the following experi-

ment. Mites were put singly into small cylindrical vessels, containing about 25 c.c. of water. Into one series of vessels, one Daphnia was placed; in a second series, two; in others, four, eight and sixteen respectively; and the time taken by the mite to catch one was noted. It was found that the time varied inversely as the number of Daphnias present. Thus the average time taken to catch a Daphnia when there were four present was approximately eighteen minutes; when eight were present, eleven minutes; and when there were sixteen, four minutes. Such a result could not have been obtained in the case of an animal tracking down its prey by its sense organs; it is apparent that ability to learn by experience could find little scope in such a process.

Many experimenters have demonstrated intelligence in the higher Crustacea and Insecta. I may perhaps again instance some experiments of my own on the Australian freshwater crayfish or yabby, *Parachaeraps bicarinatus* (unpublished data). The crayfish, placed in a box with two openings, will quickly learn always to escape by the right or left one, especially if the penalty for attempting the wrong one is not only failure to escape, but also an electric shock. On the other hand, I have never succeeded in getting them to form an association between an illuminated opening and an electric shock. If one of the two openings, irregularly or alternatively the right and left, is illuminated and at the same time electrified, they will not succeed—at least, not in 600 lessons—in learning to avoid this opening and escape by the unilluminated opening (or vice versa). One specimen which was given 440 lessons in such an apparatus, and failed completely to form any association between the light and the shock (or at any rate to regulate its movements thereby) was rested for three days at the end of the experiment (which had extended over 176 days). It was then tried again in the same apparatus, only this time there was no difference of illumination between the two exits, but the left hand opening was left permanently electrified and the right hand one free. (In the 440 trials of the first experiment, this animal had gone rather more often to the left than to the right opening.) The animal was given 80 trials at its new task, six a day. It made five errors in the first ten trials, four in the second ten, and only three in the remaining sixty.

While such experiments as these demonstrate the power of learning, they certainly suggest that it is very poorly developed. But laboratory experiments of this type can only demonstrate intelligence; they cannot measure it. It can hardly be doubted that animals will learn much more readily from the kind of experiences which they encounter in their natural modes of life. It seems extraordinary that a crayfish should learn so quickly by which of the two openings it has to escape from confinement, as long as that opening is always the same one, and yet shown no signs, even after 600 lessons, of learning that the attempt to escape through an illuminated opening is fruitless and attended by a painful sensation. But it may be that the crayfish, although (as can easily be proved) it sees the light, does not see it as part of the confinement-escape situation in the way that the experimenter does.

These experiments, in short, indicate a general capacity for learning the results of certain actions and movements. Obviously, very many of our own skilled actions have been acquired by this method of trial and error, though so much of this acquisition has come about gradually in our childhood that we are not conscious of the fact. A baby even learns how to put its finger in its mouth

by trial and error. And, indeed, the play of young animals must result in the accumulation of great stores of experience in this way. The most intelligent of animals—the mammals—begin life with a considerable period during which they are supported and protected by their parents. Thus they have time to make innumerable little experiments and gain a great amount of experience of the results of all sorts of actions before they are called upon to use these actions in matters of life and death. An animal such as an insect which has to fend for itself from the moment it appears on the scene cannot afford to experiment. It has no time for play. Its instincts must be specialized, and its actions practically perfect the first time they are performed.

How can we pass from mere intelligent to rational behaviour? The cats in Thorndike's experiment may be said to perceive that pulling the ring was followed by liberty. But it is not necessary to suppose that they understand why pulling the ring set them free. A man placed in a similar situation, if he had no previous experience at all of mechanical devices, would probably in the first instance have to discover the method of opening the door by trial and error like the cat. He would simply pull and pull at everything he could get his hands on to. But having once pulled the ring and found the door slide up, he would never have to go through all the random efforts again. This is because he would examine the connection between the ring and door; as the result of his examination he would understand why pulling the ring set him at liberty. Moreover, if he were now put into another cage in which the door was operated by a lever instead of a ring and pulley, he would immediately set about looking for some indirect way of opening the door, and would soon discover the lever.

This would be *rational* behaviour. The man is reasoning. This seems to involve power of analysis and abstraction. The man's perception is not confined to a perception of the relation between his total action and the total result. He can see the relation between the various parts of his action and parts of the result, and can abstract certain general qualities or properties from the objects exhibiting them. According to McDougall, "the essential feature of reasoning is reaction to some aspect or quality of an object which marks it as appropriate for the purpose of the moment".

McDougall, though willing to allow to animals mental processes more like those of man than many psychologists are prepared to do, yet considers that it is difficult to point to behaviour that clearly implies reasoning in any animals lower than the apes. But it appears that the rudiments of this higher type of behaviour, even if not sufficiently developed to be called reasoning, can be traced further down than the apes. Thorndike found that cats trained to open a cage by pulling on a ring, when placed in a similar cage in which the door had to be opened by depressing a lever, learnt the new lesson more quickly than cats which had not the previous experience. McDougall relates how his dog learnt to open a puzzle box containing food. Before opening the lid (by depressing a lever) it was necessary to turn a horizontal button and push down a hinged board. It would perform these two preliminary operations, sometimes with its paw, and sometimes with its nose, and not always in the same order. Such behaviour seems to imply more than mere formation of associations between certain acts and the pleasure or pain of their results.

Do animals have ideas involving memory images of past experiences and the basing of plans for future action on them? Even the simplest forms of learning

must involve memory, of course, but this does not necessarily mean that the animal has conscious recollection of its previous experiences. Let us take the example of an animal trained to escape from a box by the less brightly illuminated of two openings. Before training it escaped by either opening indifferently. But as a result of experiencing a painful electric shock whenever it went to the brighter opening, it now always chooses the other. This does not necessarily mean that it consciously remembers its previous experiences, and bases its action on this memory. It may be that it simply perceives the situation now differently from the way in which it did before its training. It now confronts the two openings with a dread of the bright opening, and possibly an attraction towards the darker one, without necessarily actually forming a memory image of its previous experiences.

A consideration of instinct indicates that the fact that the animal has come to dread the bright opening does not necessarily imply that it has conscious memory of its past experiences. We can compare the dread of the bright opening with the instinctive fear which many animals have of their natural enemies, or that nearly all higher vertebrates experience when they find their movements restricted; and here there is no question of memory, at any rate on the first occasion on which the fear is felt. And this suggests an extremely interesting problem, of which we can only conjecture the answer—what mental states accompany the first performance of an instinctive act? When a bird starts out to build its first nest, has it any idea of what the result of its activity will be? When an Ammophila wasp sets out to search for its first caterpillar, has it any idea of the appearance of the object of its search? Or when it has sighted one, has it any sort of expectation or premonition of what the rest of its action towards it is going to be?

McDougall believes that every instance of instinctive behaviour involves a knowing of some thing or object, a feeling in regard to it, and a striving towards or away from that object. He maintains that a bird has innate representation of the form of the nest which it is going to build.

Lloyd Morgan (1913) will allow less than this. He considers that at its first performance of an instinctive act the animal has only a vague feeling of interest in what is coming, rather than a perception (or "preperception") of the goal.

We can only guess at the mental state of the animal about to perform an instinctive act for the first time, not only because of our general ignorance of the mental states of the lower animals, but also because of our own lack of specialized instincts, involving the performance of long and complicated action; we can, therefore, draw little analogy from our own experiences. All our actions, except such simple instinctive ones as hitting a man when we are angry, or running away from danger, have been learnt, and we, therefore, have a memory image to act as goal for our activities. It is interesting to speculate on the different form that the science of psychology might have taken had human beings been endowed with even one complicated mode of instinctive action, involving a long series of actions like those of a solitary wasp stocking its nest with paralysed prey, or a bird building its nest.

Although it seems absurd to question the presence of anticipatory images where previous experience is involved, the consideration of instinct makes it more difficult to be sure that memory images are also present. But it is possible to produce experimental evidence upon this point. This is provided by the "delayed

reaction" type of experiment. The animal is shown, by a light, from which of a number of compartments food can be obtained. At varying intervals after the extinction of the light the animal is released and the percentage of correct reactions is recorded. All mammals experimented on show the ability to choose the correct compartment after short intervals, but in some cases this depends upon the animal being allowed to maintain its orientation during the interval. On seeing the light (the association between light and food having been produced by preliminary training) the animal points its head in that direction, and on release it follows up that direction. Dogs and raccoons, however, do not require this aid. The evidence from the delayed reaction type of experiment is conveniently summarized by Washburn (1926).

In his fascinating book on the mentality of apes, Köhler gives many instances of the chimpanzee's ability to think of absent objects.

Consider this account of the behaviour of the solitary wasp, *Pompilus scelestus* (Peckhams, 1905). The wasp arrived at her nest with a spider, which proved too big to go into the hole. She pushed it out again, and carried it away to a place of safety among some clover blossoms. "She then washed and brushed herself neatly, and took several little walks, so that it was fully fifteen minutes before she began to enlarge her nest." During that interval she must have carried in her mind the idea of enlarging the nest to receive the spider.

However, we are getting into those regions of animal psychology which are furthest from the ordinary conceptions with which the zoologist works. Let us turn to those aspects which make closest contact with the general biologist.

What about the evolutionary aspect of the various grades of mental development which we find in the animal kingdom? Can the higher modes of mental life be derived by mere elaboration from the lower, or have we to postulate the appearance of something really new during the course of evolution? And the same problem occurs lower down. Are vital processes, such as embryonic development, of the same nature, fundamentally, as the behaviour of the organism as a whole in relation to its external environment, having, therefore, a psychical as well as a physical aspect? A full consideration of the second point would lead us very far into a discussion of the relation of the three great categories, inorganic processes, vital processes and conscious behaviour, and it would clearly be impossible to tack on such a discussion to the end of an evening's lecture. But it is worth recalling that many psychologists see no difficulty in uniting the last two categories. To quote McDougall again, "according to this view, then, not only conscious thinking, but also morphogenesis, heredity and evolution are psychophysical processes" (1911).

It is easier to relate vital processes to instinctive than to intelligent behaviour. No valid evidence seems to be forthcoming that learning by experience occurs in vital processes. It is clear, of course, that these may adapt themselves to circumstances—as in the development of a partial embryo into a complete adult, or the development of appropriate buttresses in bones subjected to unusual stresses. Roux, indeed, distinguished two phases even in normal development. A first stage in which organs develop irrespective of functioning, and a second in which they complete their development in response to functioning. But there is no valid evidence to show that such adaptations occur more readily or more perfectly as a result of experience; that is to say, as a consequence of the discovery,

by trial and error, that certain modes of growth gave more favourable results than others.

The result (as distinguished from the process) of learning by experience is a disposition to act in a certain manner when confronted with a certain object or situation; and once it has been formed, a learnt disposition seems to differ in no essential way from an innate disposition or instinct, except that it is usually less enduring. Are we then to suppose that instincts are the result of learning in past generations? This is, on the face of it, such a plausible way of accounting for specific instincts that psychologists have always tended to a belief in Lamarckian inheritance. McDougall's well-known experiment (still in progress) on inheritance of training in rats would seem to afford support to this view. It will be recalled that he trained rats to escape from a tank of water by the less brightly illuminated of two exits, and found a progressive decline in the average number of repetitions required to learn the lesson as the number of generations of training increased (McDougall, 1930). It would be unsafe to build any superstructure of theory on the result of his experiment before it has been repeated and confirmed, but, taken at its face value, the result of this experiment certainly seems to be in accord with the ideas of those who look upon instincts as inherited habits.

There are, however, very serious difficulties in the way of accepting such a theory as a general explanation of the relation between innate and learnt dispositions. There seem to be many instincts for which such an origin could not be postulated; for instance, actions which are performed only once in a life-time (such as cocoon-spinning in insects) and often after the germ cells are already cut off from organic connection with the body (many cases of copulation and oviposition).

Nor is it easy to conceive how increased facility in forming a specific mental disposition by association between certain actions and the consequent pleasure or pain could eventually result in its formation by the cell differentiations and cell movements which constitute embryonic development. This difficulty (inherent in all Lamarckian explanations) is surmounted by McDougall in a manner which few biologists would have the courage to suggest. He suggests (1911) that the structure of the germplasm may not be the only link between generations, but that there may be an enduring psychic existent of which the lives of individual organisms are but successive manifestations.

Whatever view one may hold as to their genetic relations, the fact that mental dispositions may be innate or formed as the result of experience is of the deepest significance to biological theory.

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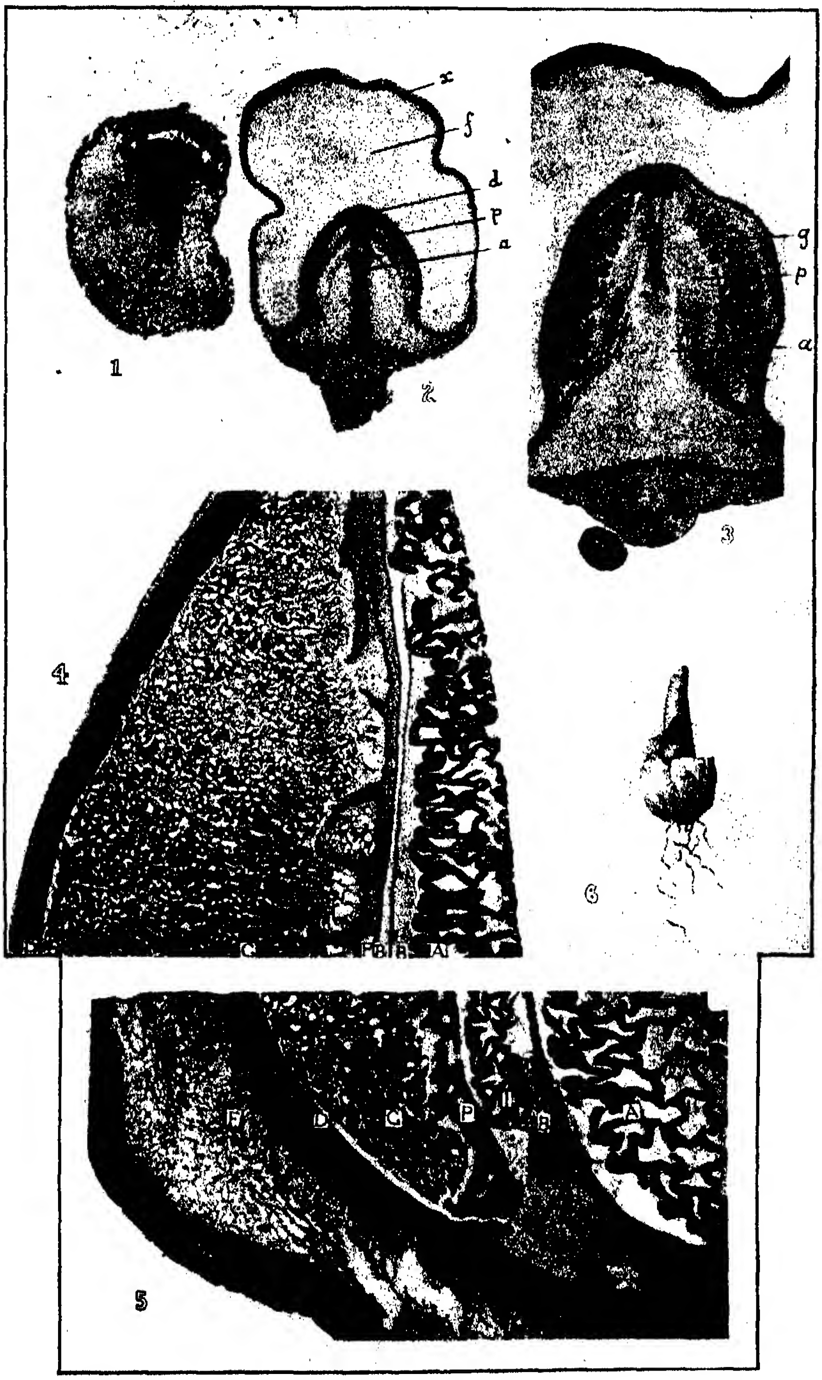
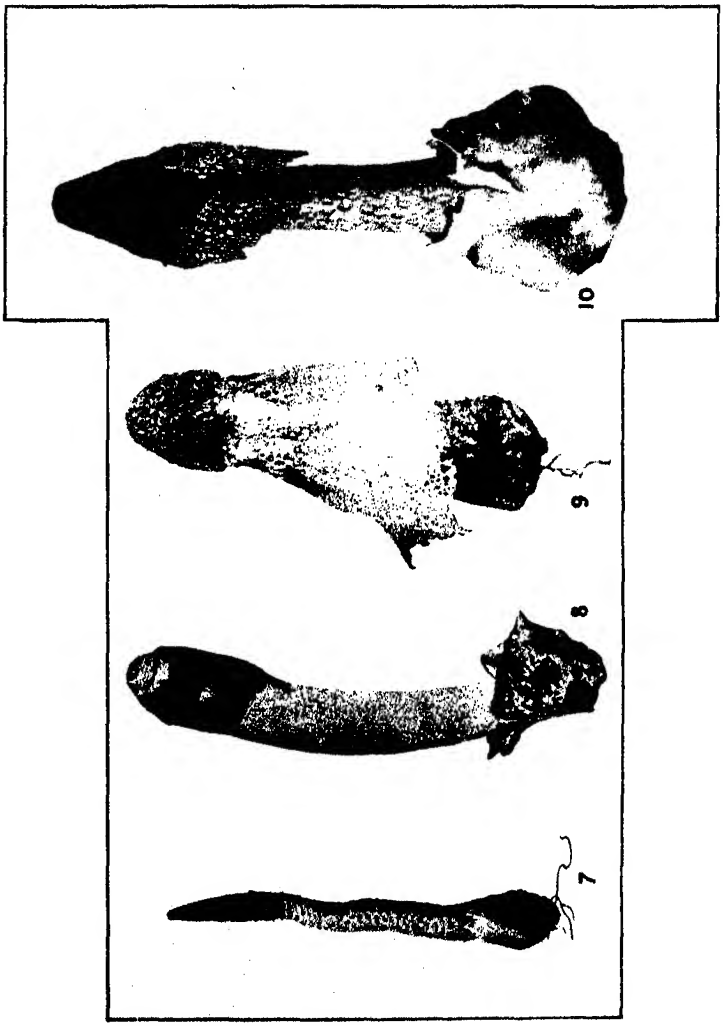
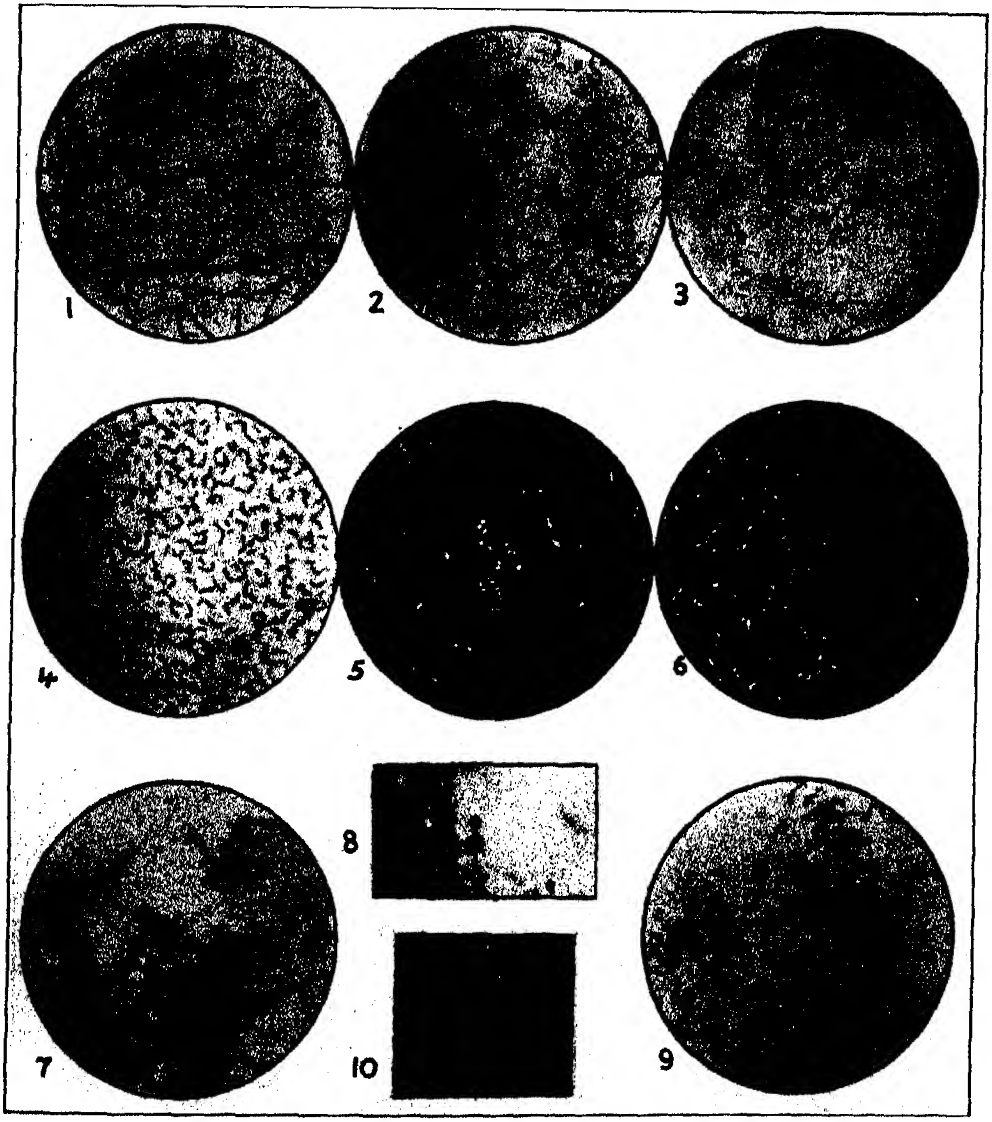


Gasteromycetes of Australasia—Phallales.



Gasteromycetes of Australasia—Phallales.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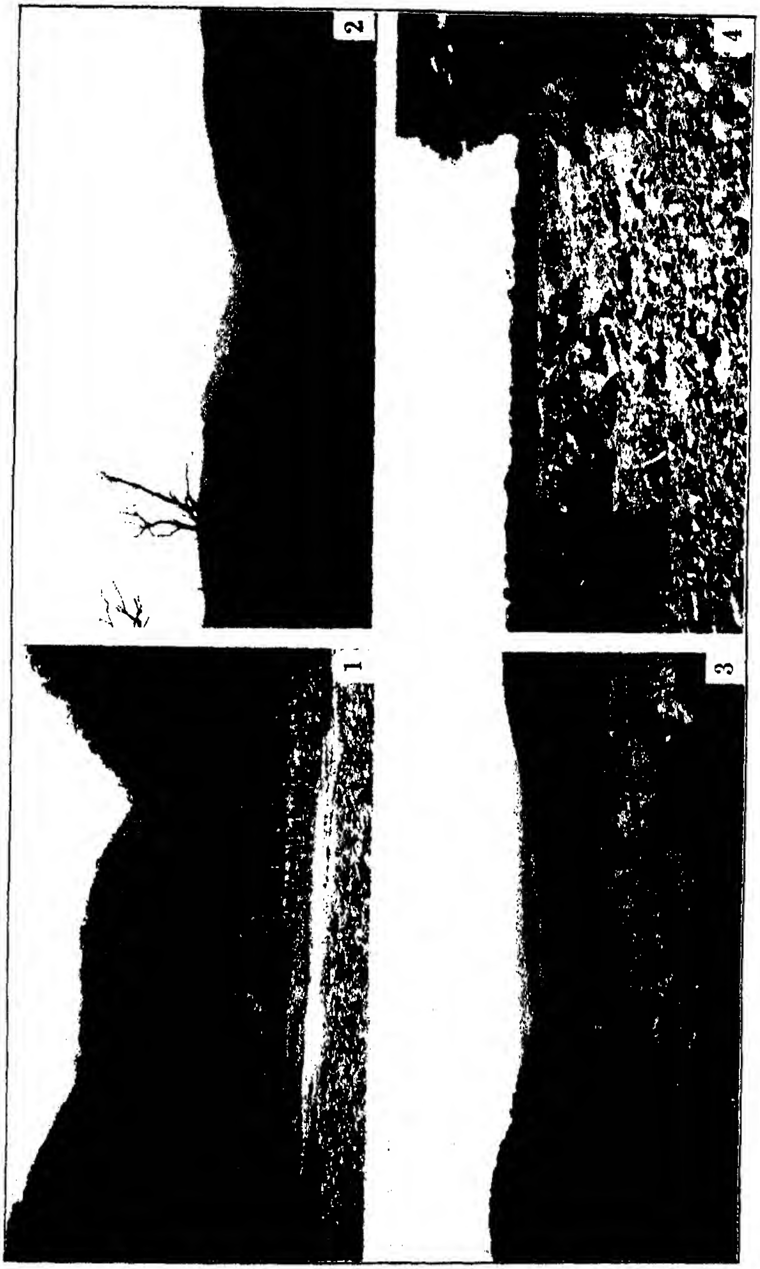
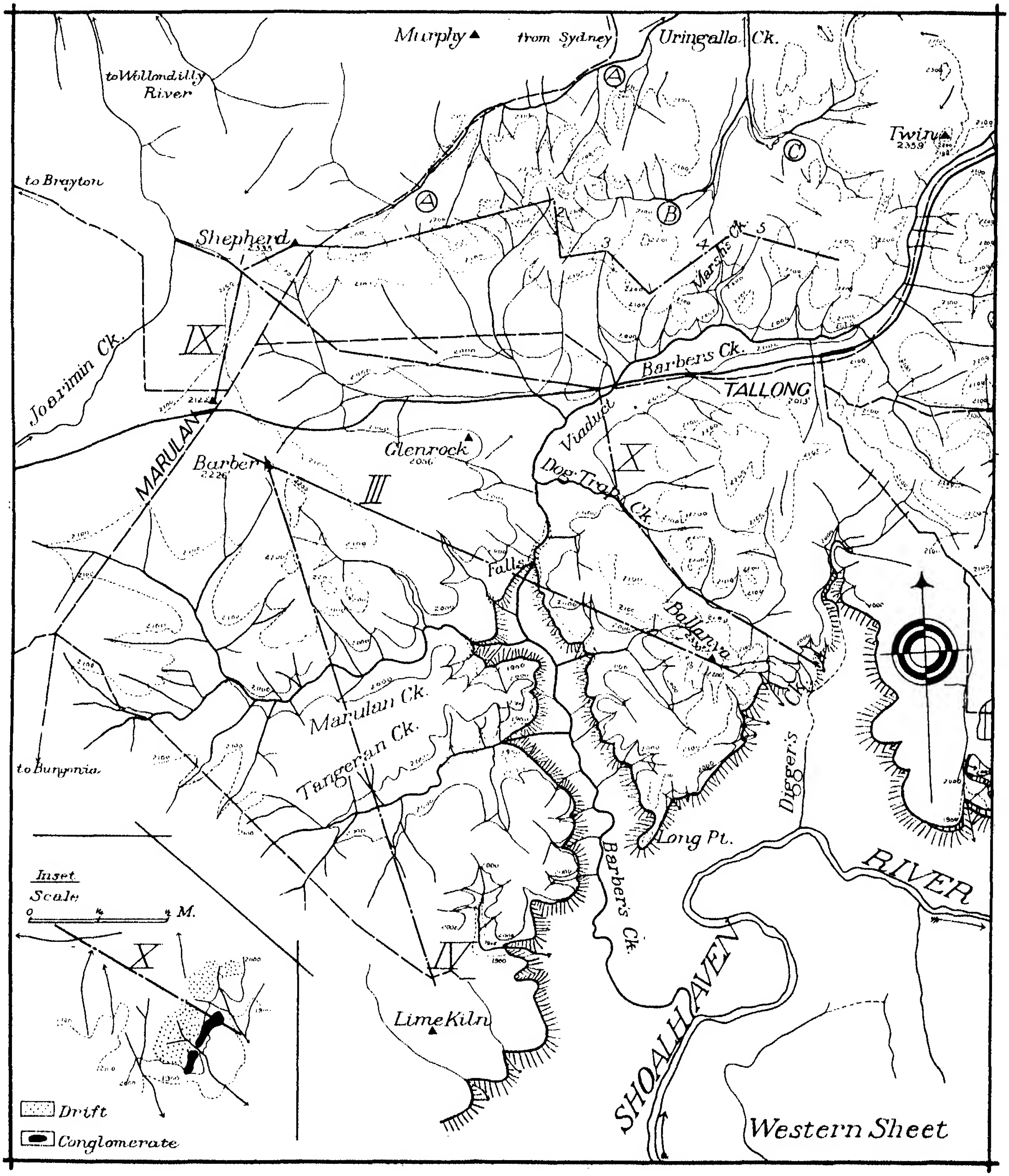


Physiography of the Shoalhaven River Valley.


Murphy
from Sydney
Uringalla Ck.
to Wollondilly River
Twin 2359
to Brayton
Shepherd 2335
Marsh's Ck.
IX
Joarimin Ck.
Barbers Ck.
TALLONG 2013
MARULAN
Glenrock 2056
Viaduct
Barber 2226
III
X
Dog Trap Ck.
Falls
Bullanya Ck.
Marulan Ck.
Tangeran Ck.
to Bungonia
Digger's Ck.
Long Pt.
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RIVER
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Inset
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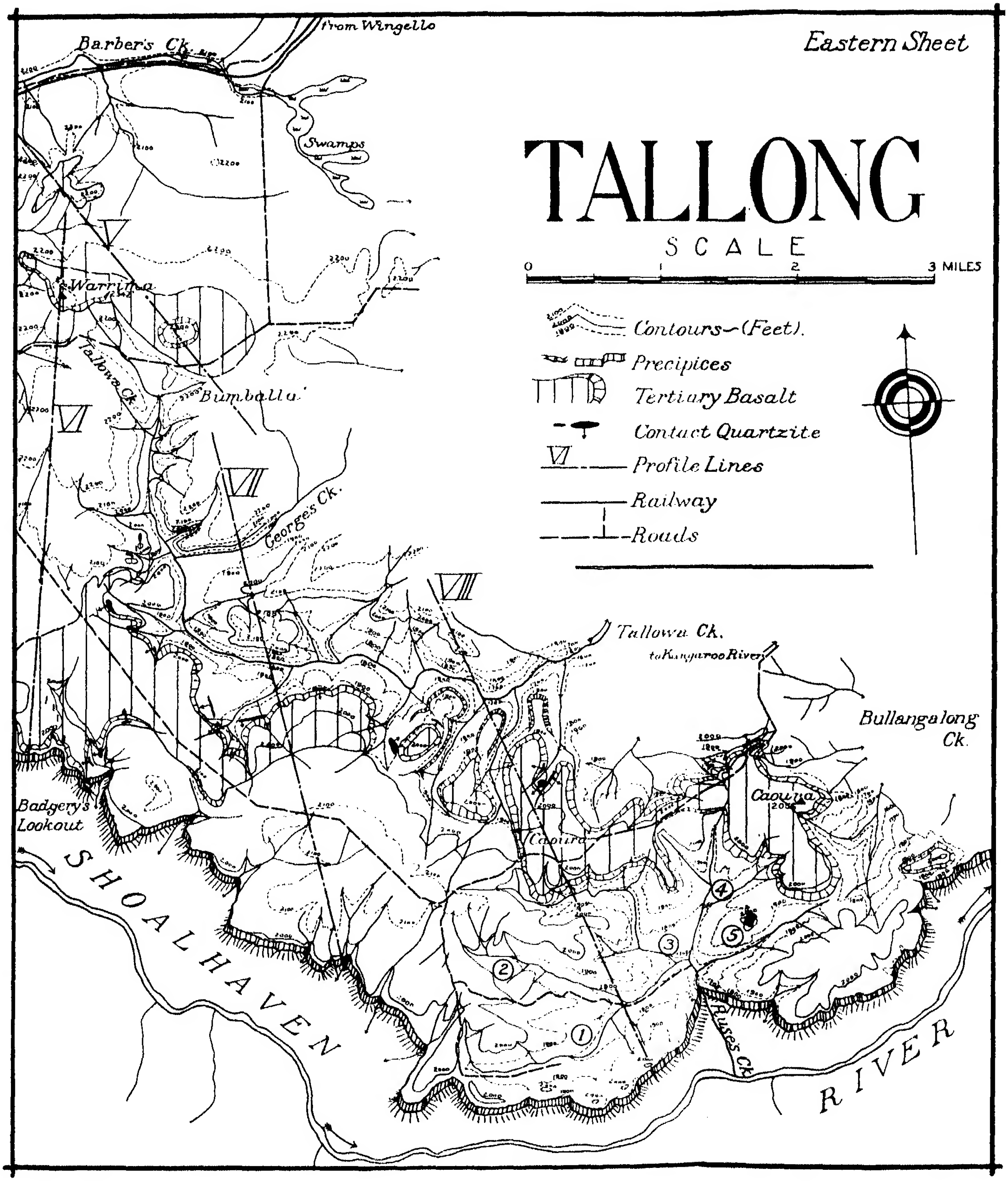
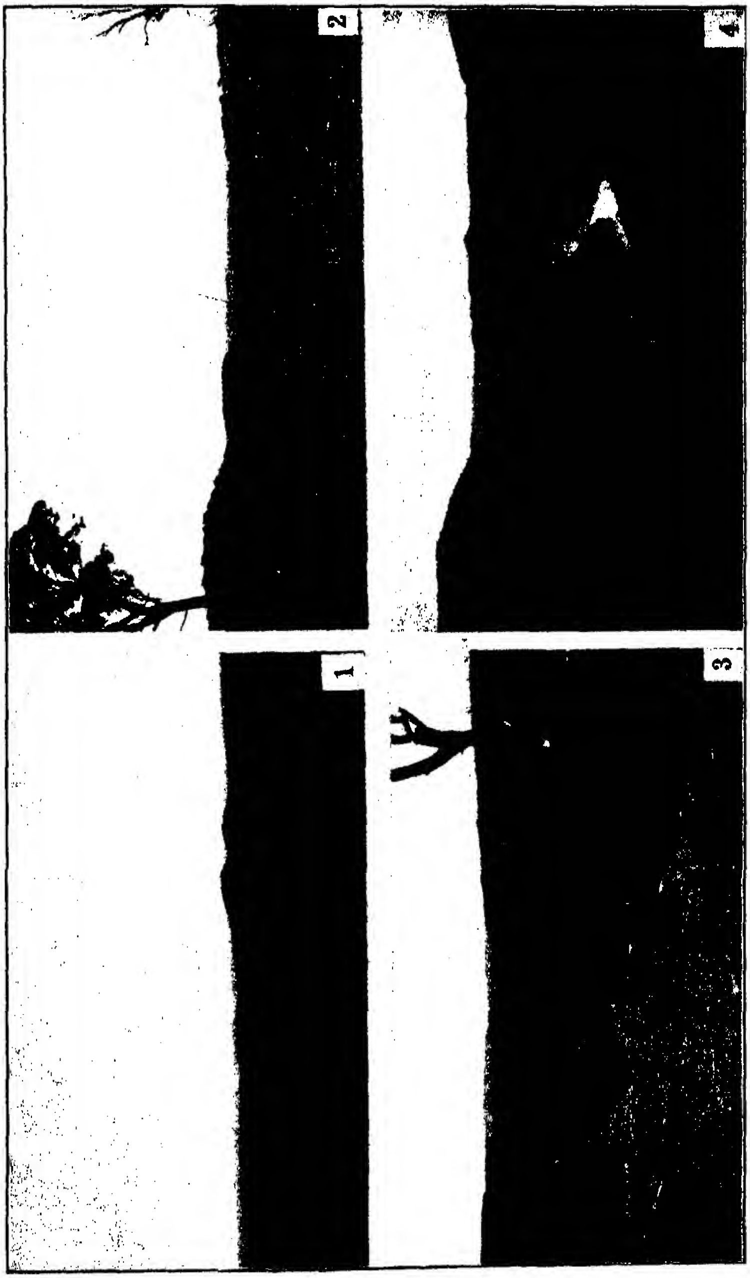
IV
Lime Kiln
Drift
Conglomerate
Western Sheet


Eastern Sheet
TALLONG
SCALE
0 1 2 3 MILES
Contours—(Feet).
Precipices
Tertiary Basalt
Contact Quartzite
Profile Lines
Railway
Roads
from Wingello
Barber's Ck.
Swamps
Warrina
Tallowa Ck.
Bumballa
George's Ck.
Tallowa Ck.
to Kangaroo River
Bullangalong Ck.
Caoura
Badgery's Lookout
SHOALHAVEN
RIVER
Ruses Ck.



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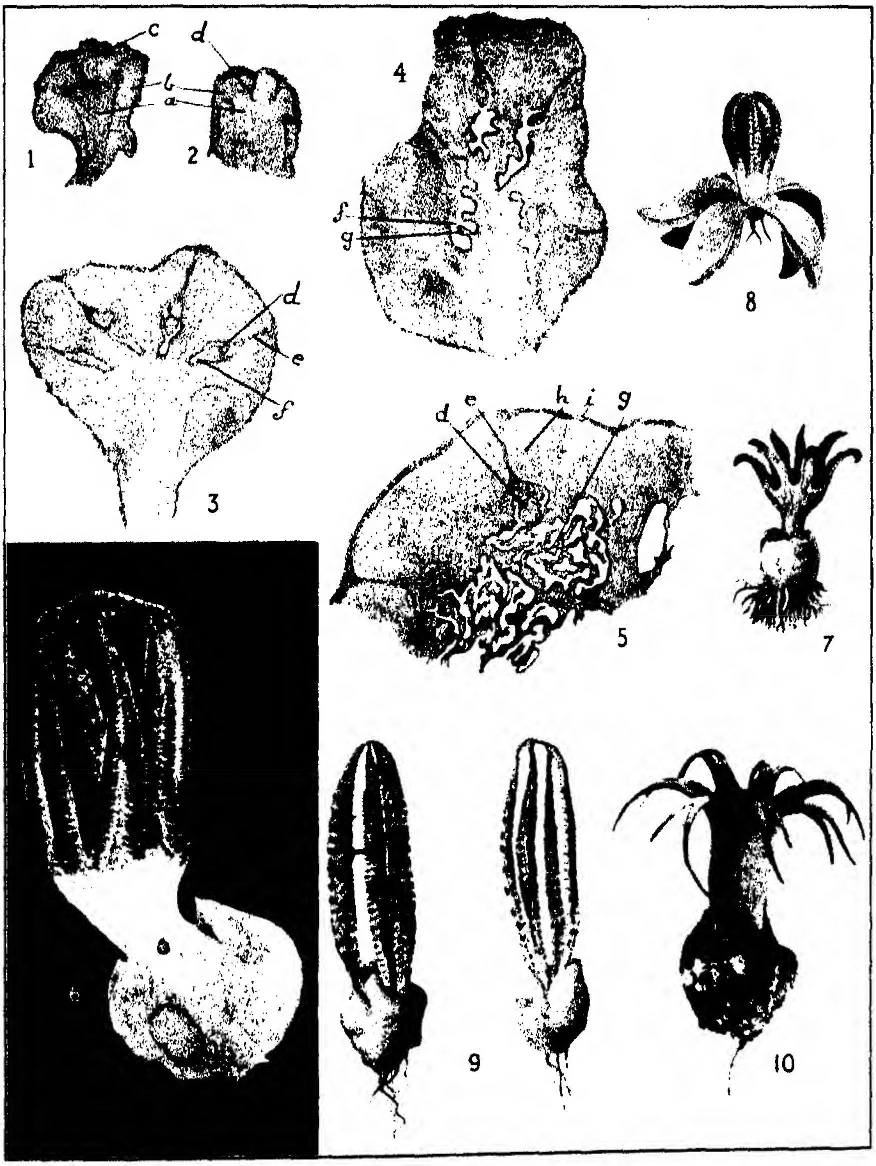
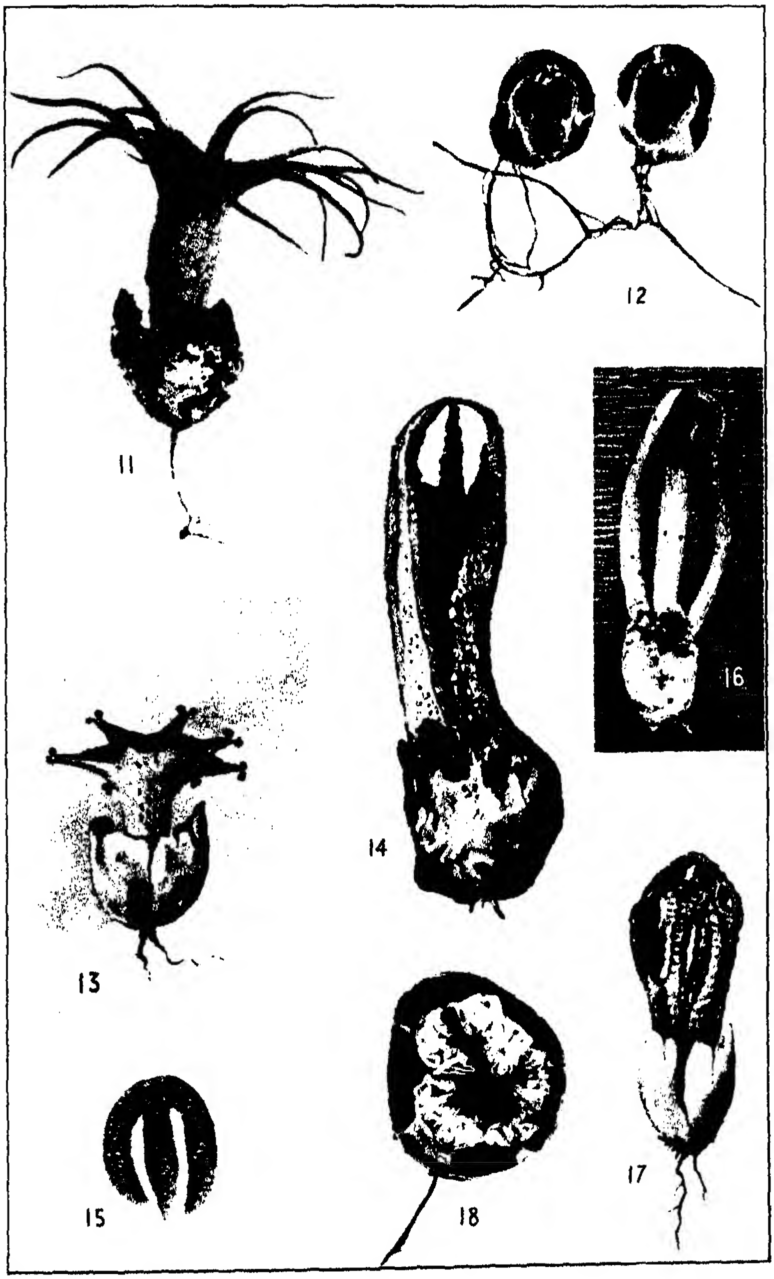
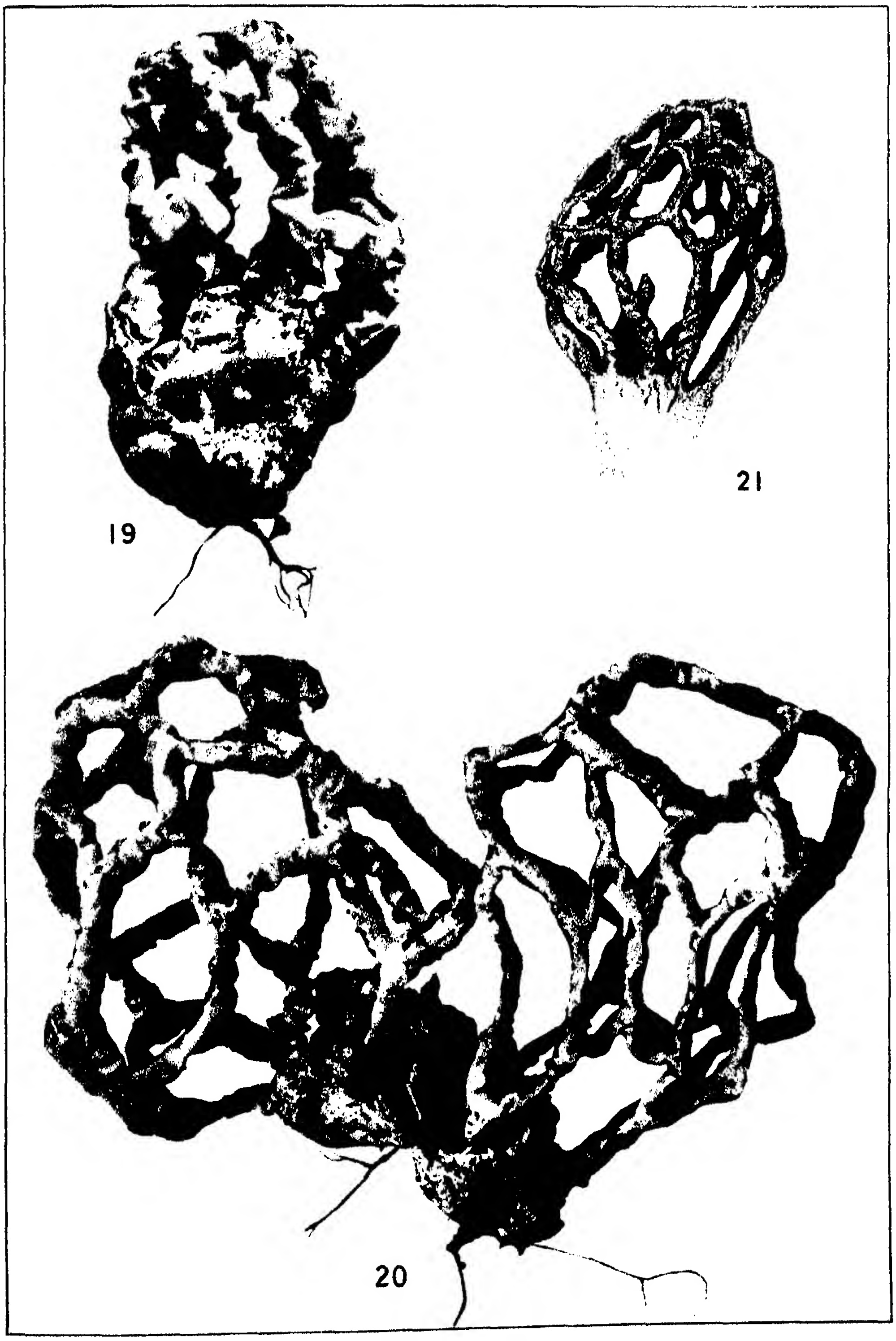


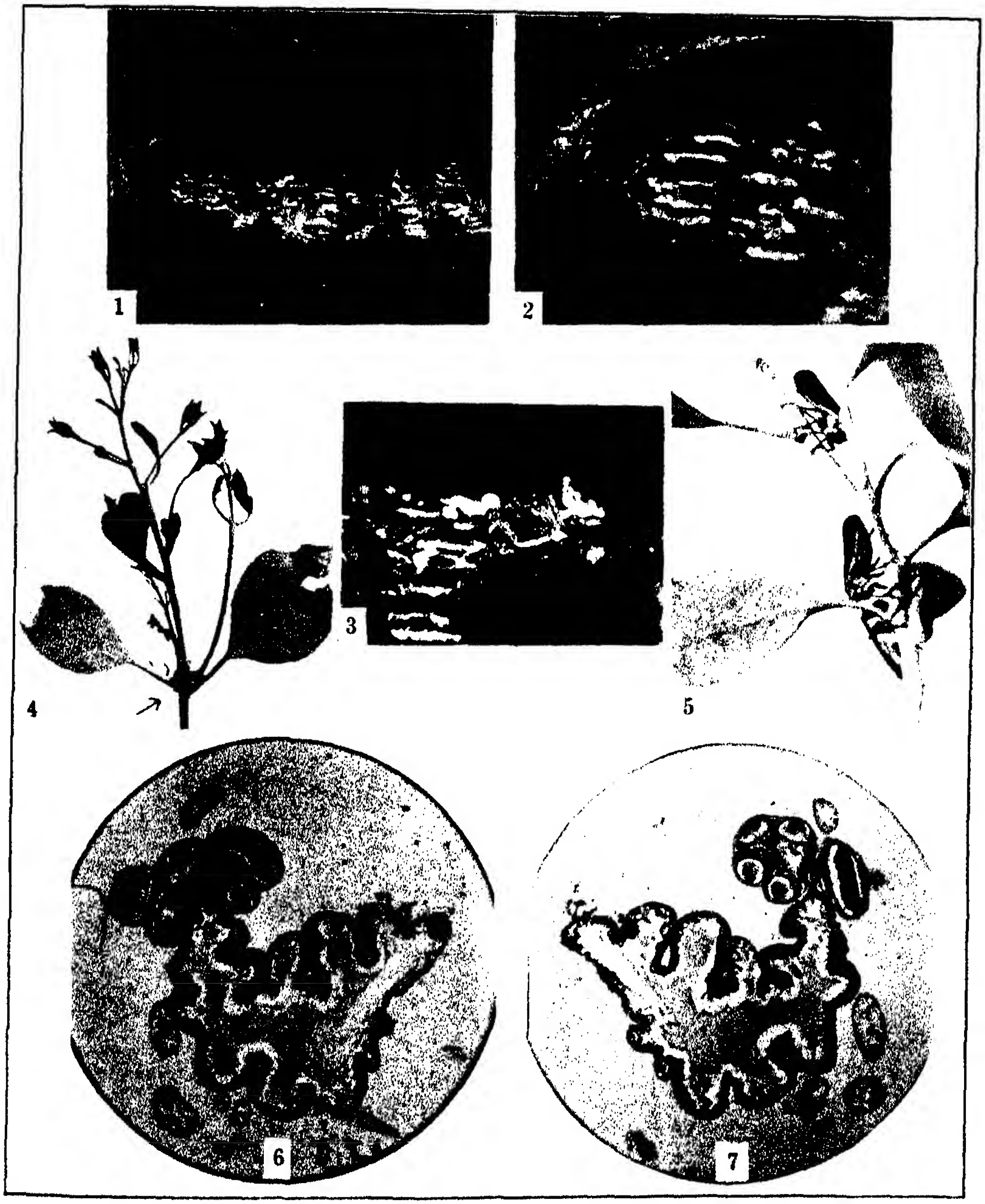
Australasian Clathraceae.



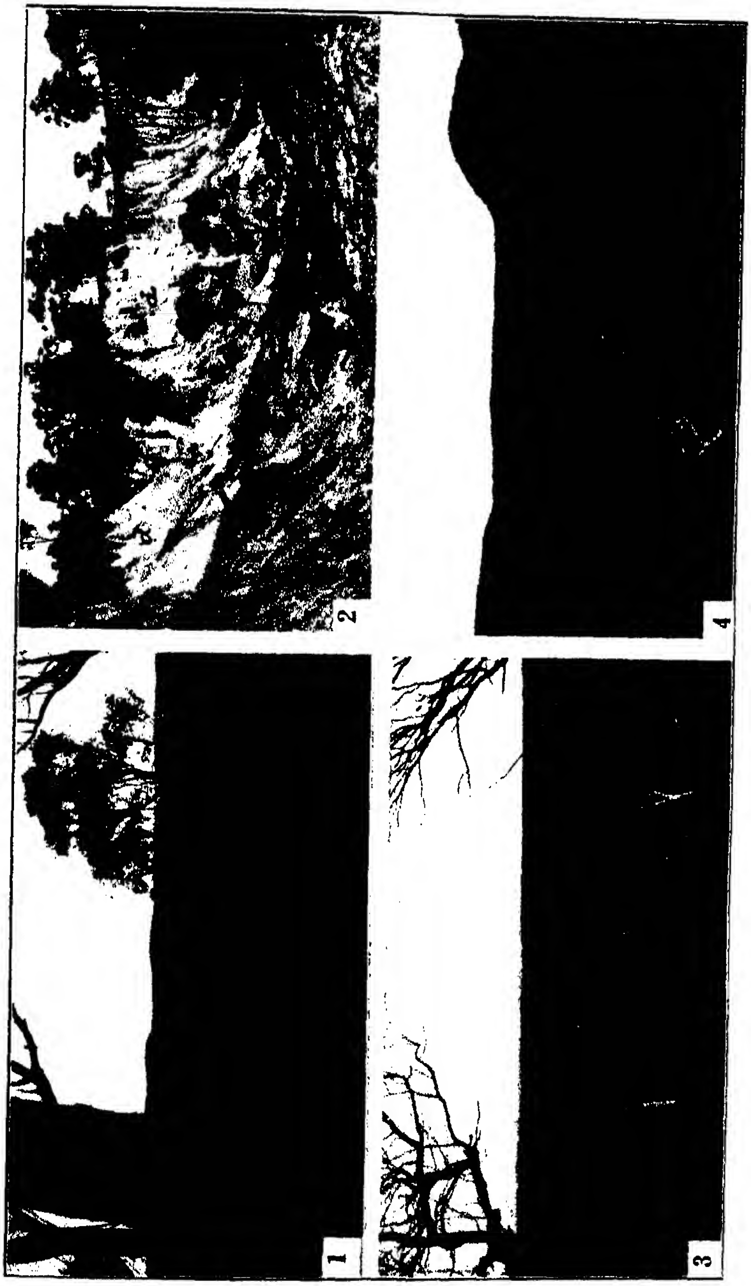
Australasian Clathraceae.



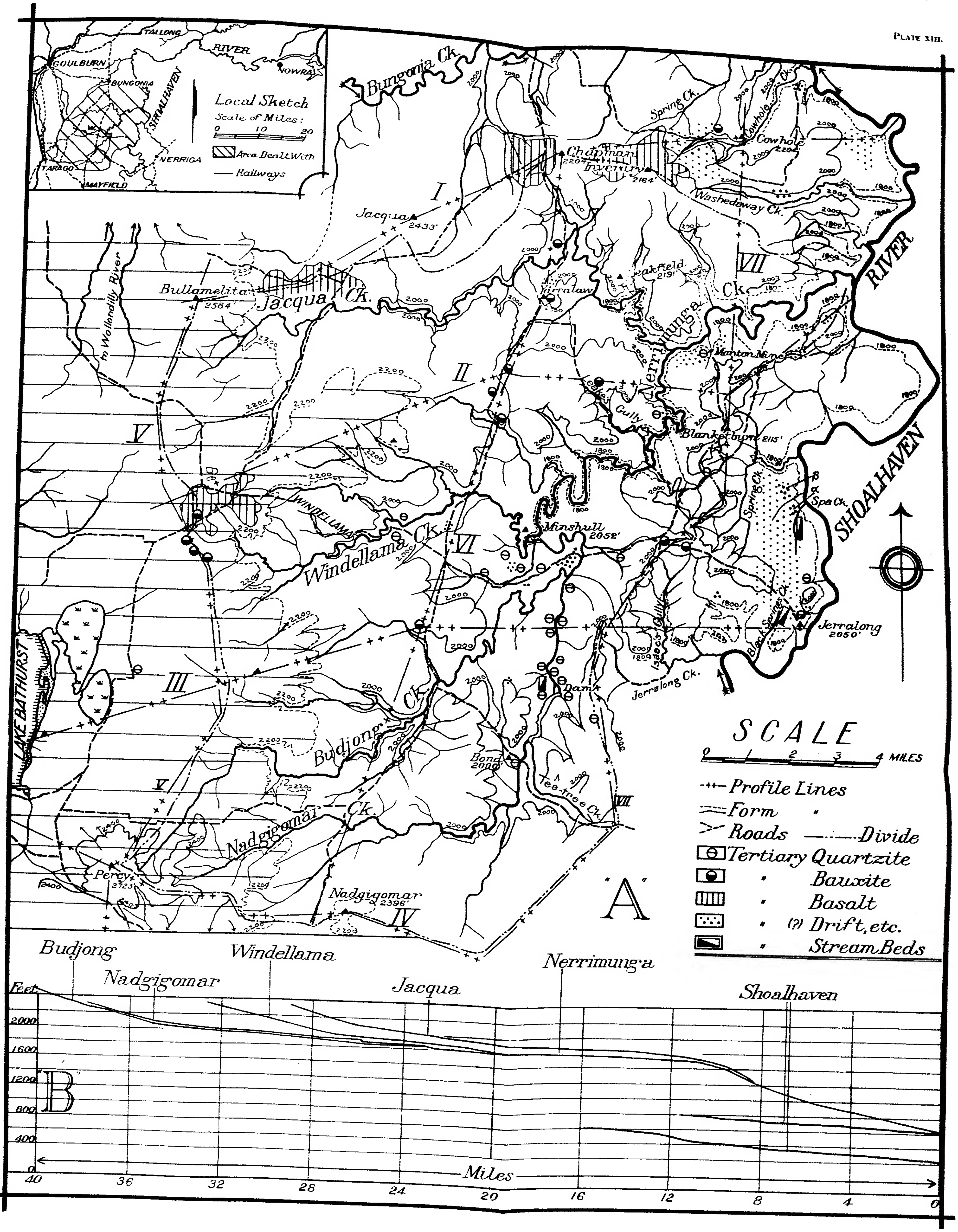
Australasian Clathraceae.



Eurymelinae.



Physiography of Shoalhaven River Valley: Nerrimunga Creek.


Local Sketch
Scale of Miles:
0 10 20
Area Dealt With
Railways
GOULBURN
TALLONG
RIVER
NOWRA
BUNGONIA
SHOALHAVEN
NERRIGA
TARAGO
MAYFIELD
Bungonia Ck.
Chapman 2207'
Inverary 2164'
Spring Ck.
Cowhole
Cowhole Ck.
Washedaway Ck.
RIVER
SHOALHAVEN
Jacqua 2433'
Bullamelita 2584'
to Wollondilly River
Jacqua Ck.
Oakfield 2191'
Nerrimunga Ck.
Manton Mine
Blanketburn 2115'
Gully
Minshull 2052'
Windellama Ck.
WINDELLAMA
Spring Ck.
Spa Ck.
Jerralong 2050'
Black Springs Ck.
Isaacs Gully
Jerralong Ck.
Dam
Budjong Ck.
Bond 2000'
Tea-tree Ck.
Nadgigomar Ck.
Nadgigomar 2396'
Percy 2723'
LAKE BATHURST
I
II
III
IV
V
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VII
VIII
SCALE
0 1 2 3 4 MILES
Profile Lines
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Roads
Divide
Tertiary Quartzite
" Bauxite
" Basalt
" (?) Drift, etc.
" Stream Beds
"A"
Budjong
Nadgigomar
Windellama
Jacqua
Nerrimunga
Shoalhaven
Feet
2000
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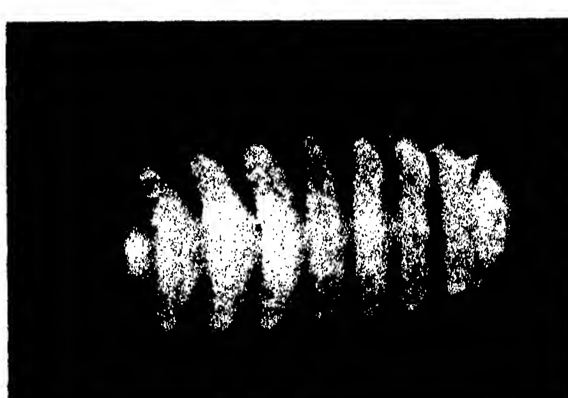
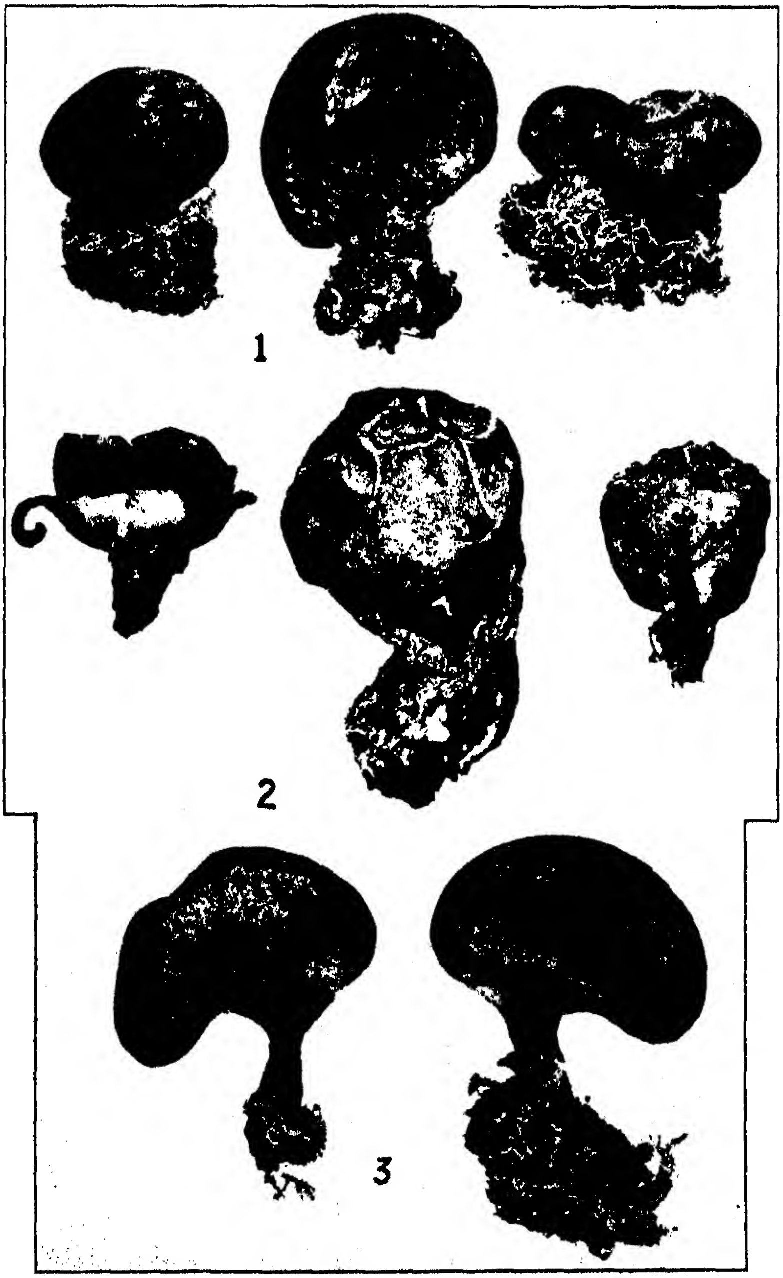
800
400
0
"B"
Miles
40 36 32 28 24 20 16 12 8 4 0

1.

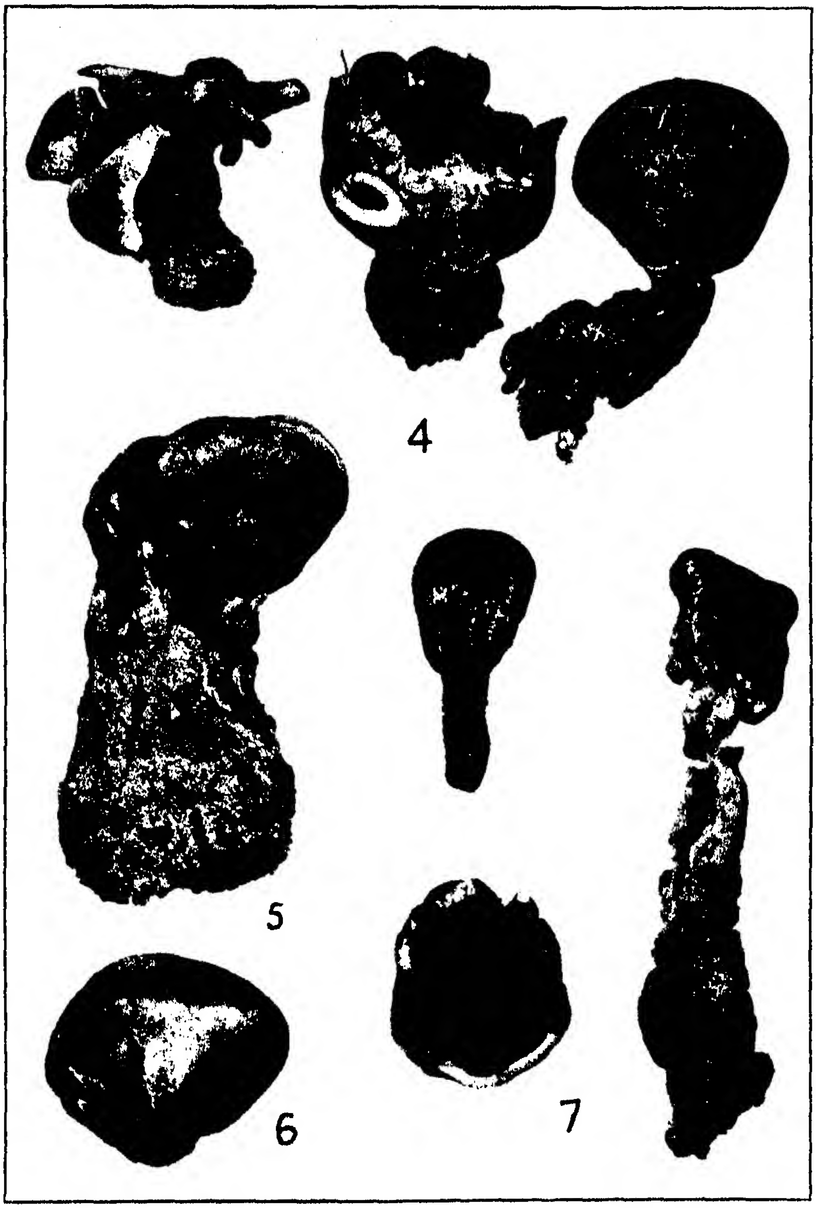


2.

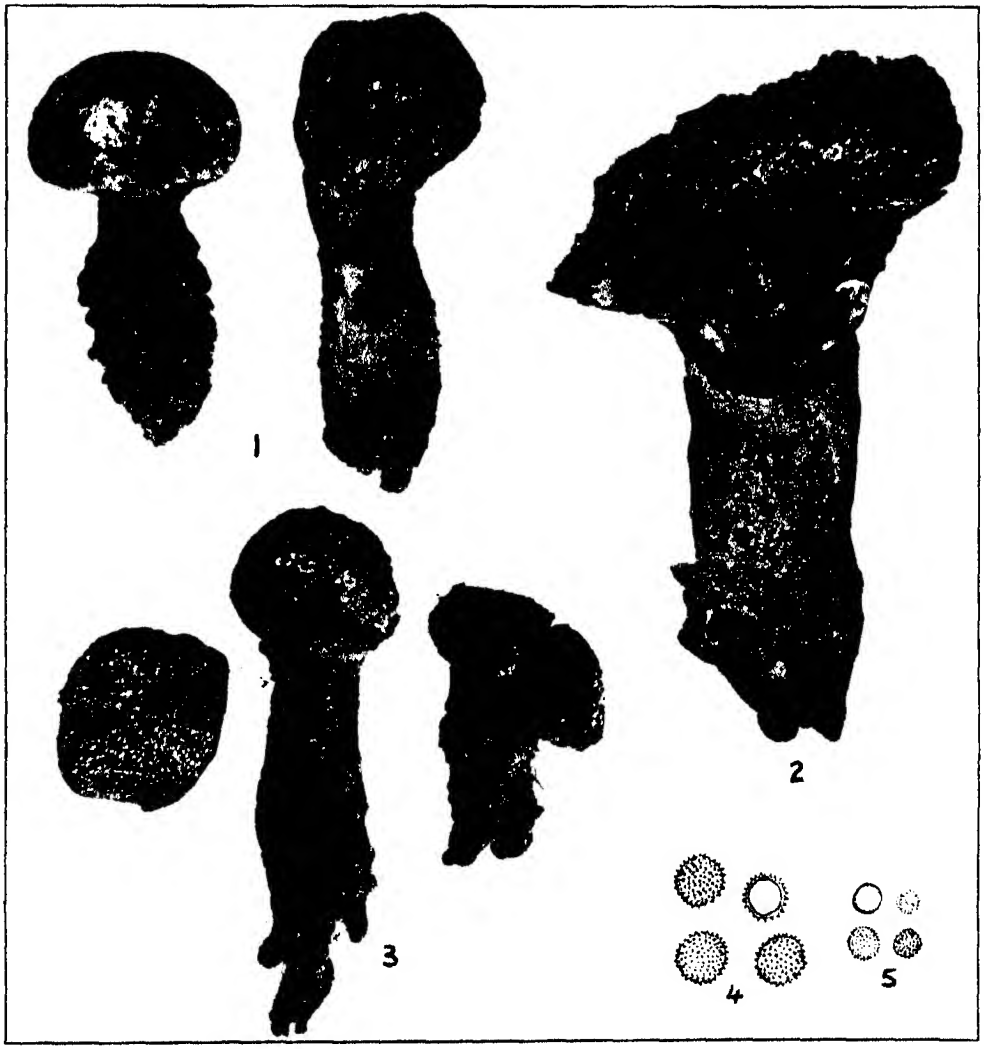
Crassione aristaei, n.g. et sp. 1. Female (× 6); 2. Male (× 15).



Scleroderma spp.



Scleroderma spp.



Pisolithus spp.

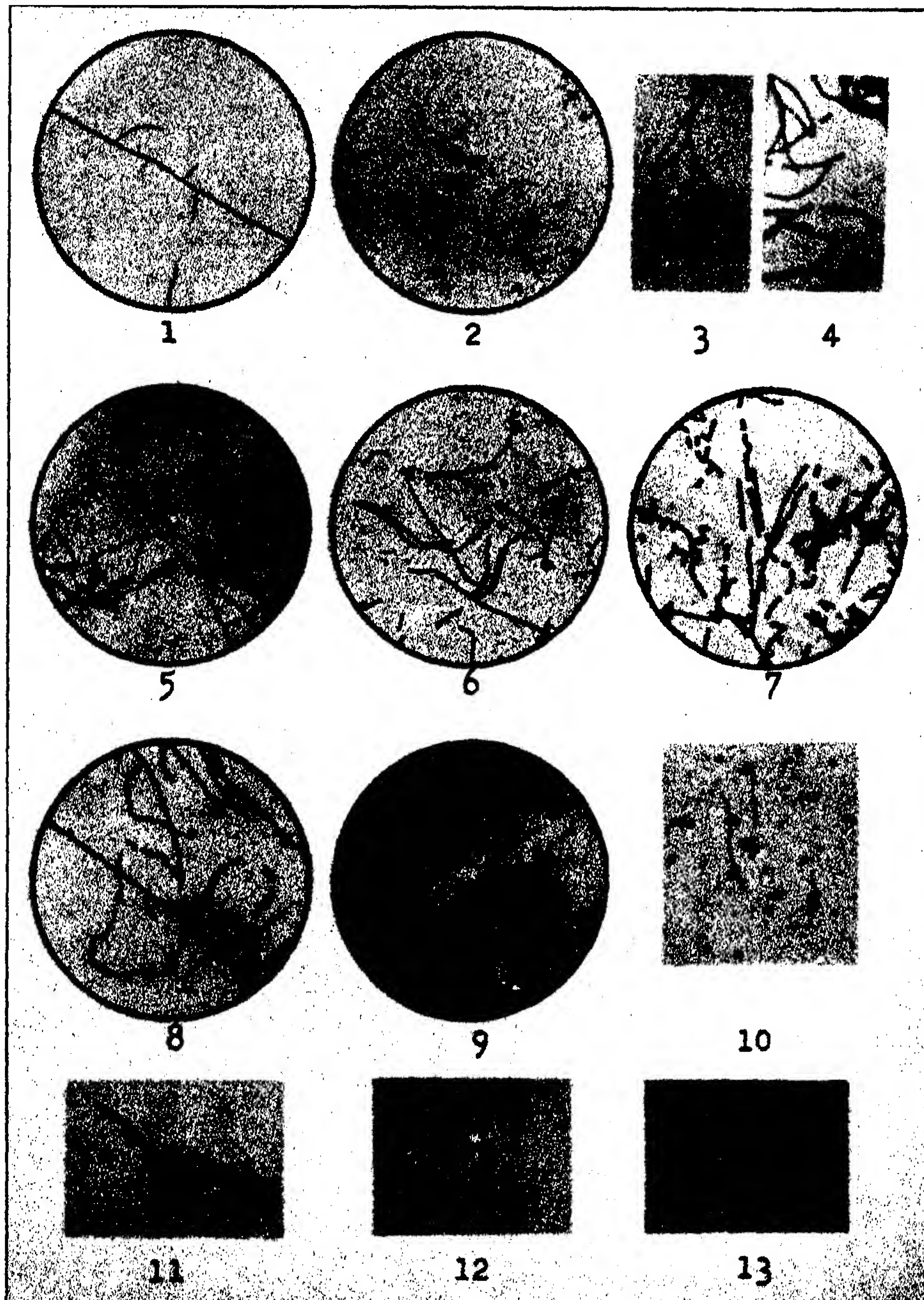
1. Vigorous community of *Stipa nitida*.

2. Tussocks of *Stipa nitida*.

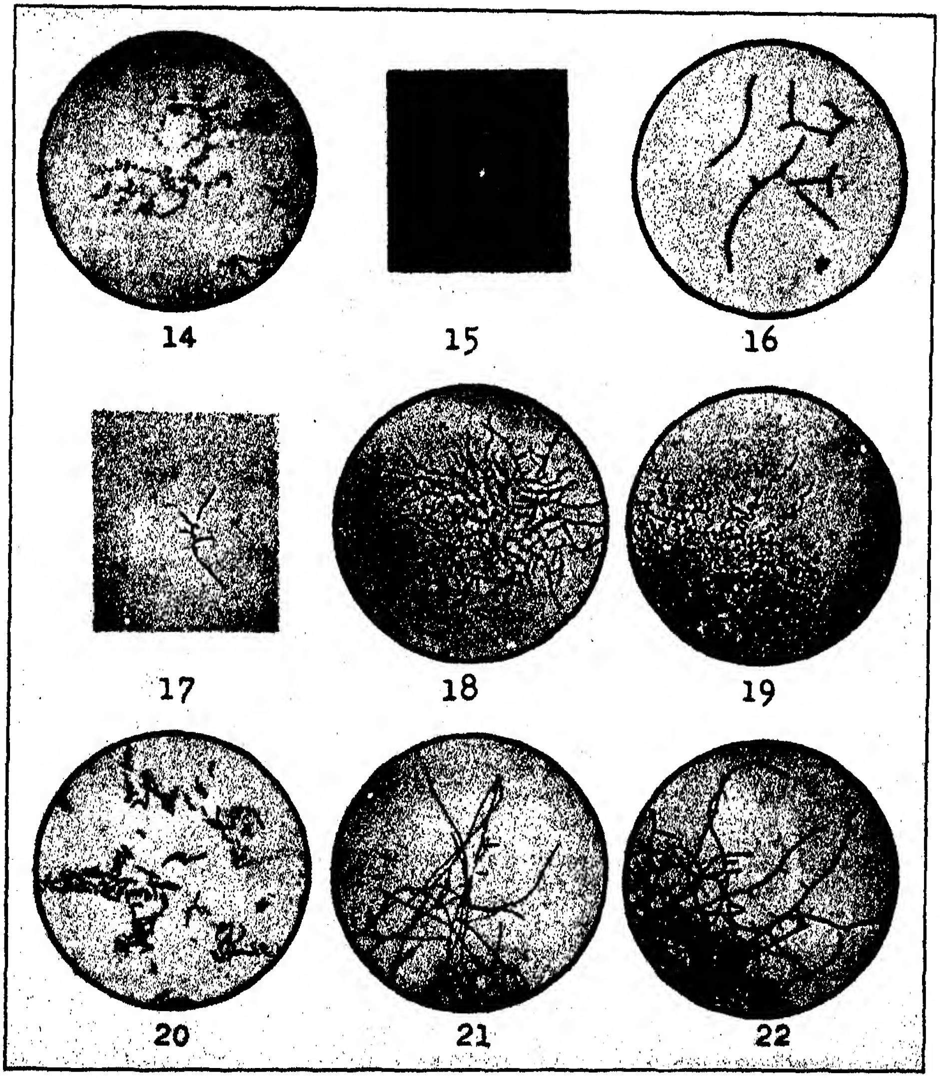
3. Growth inside Reserve.

4. Absence of growth outside Reserve.

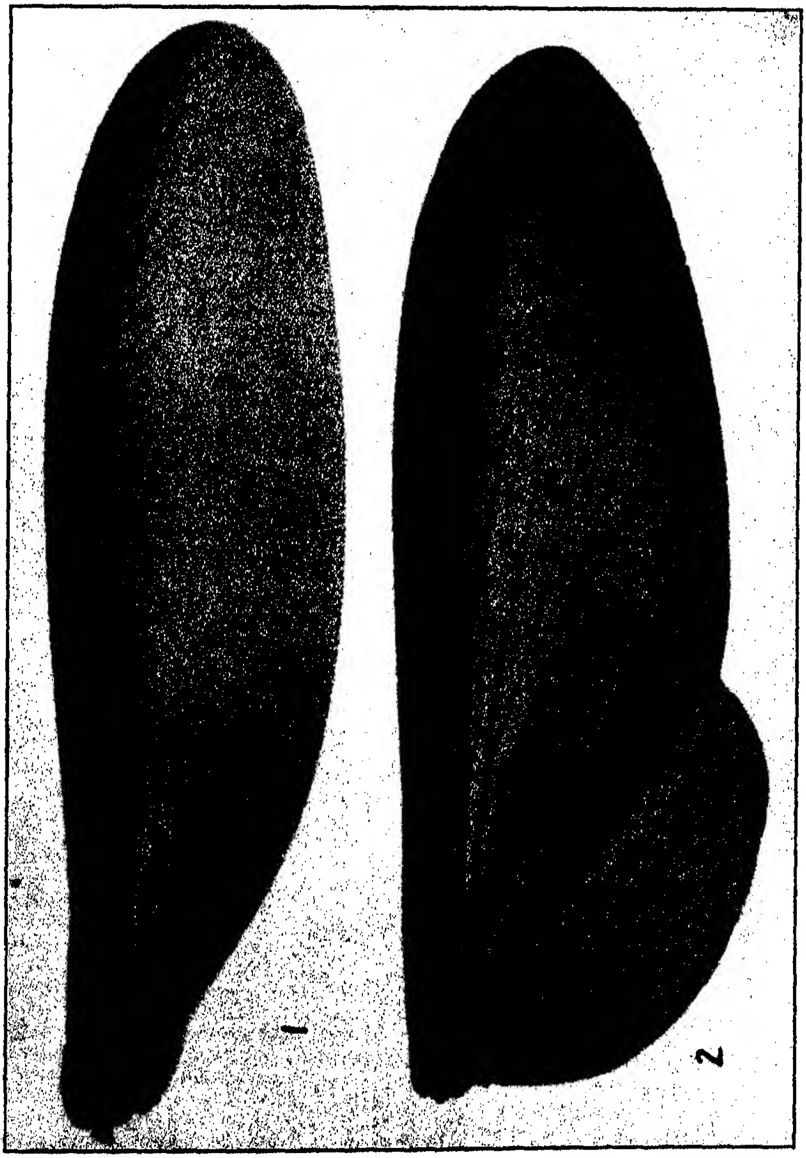
Photographs 3 and 4 taken on the same day.



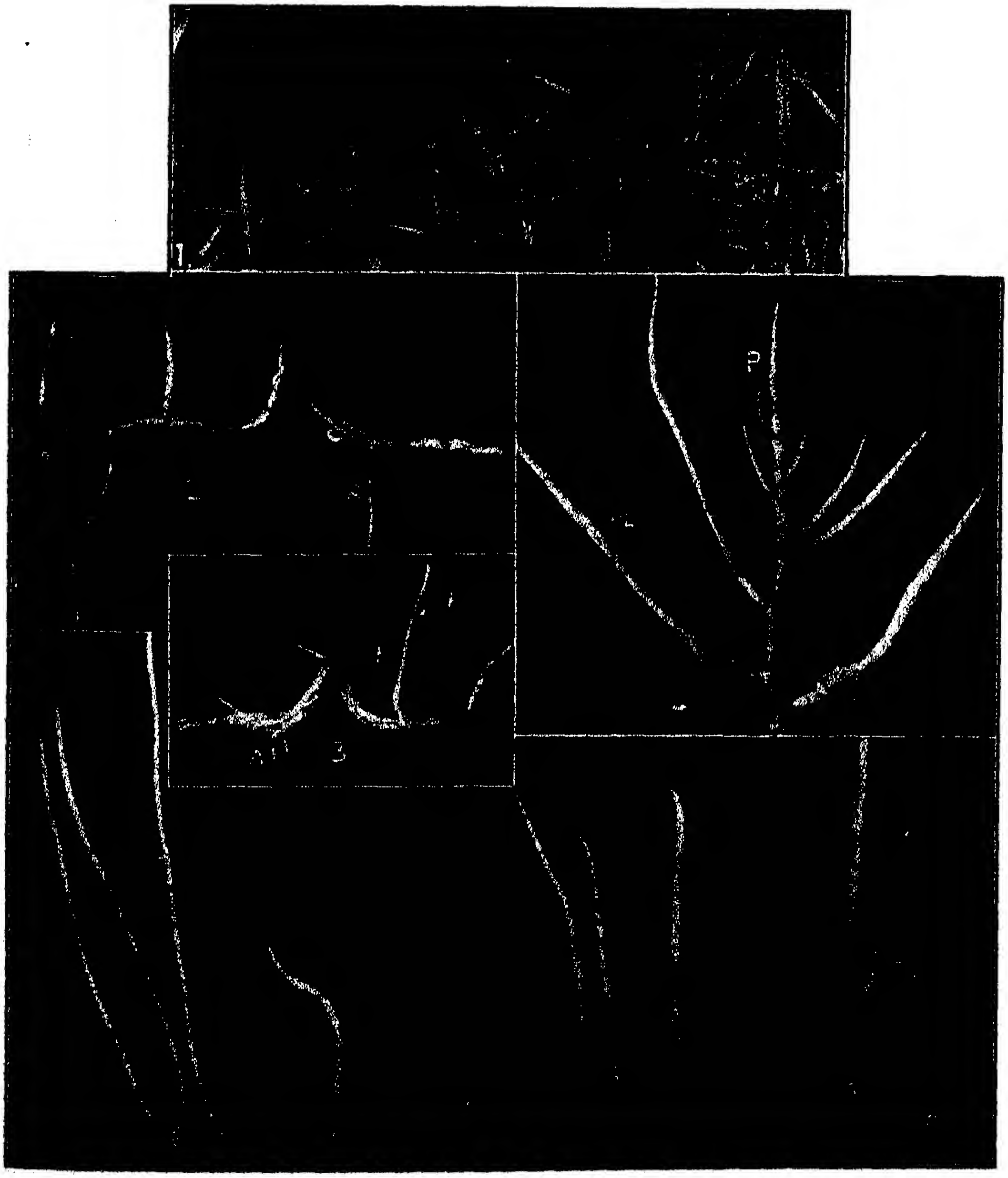
Actinomyces spp.



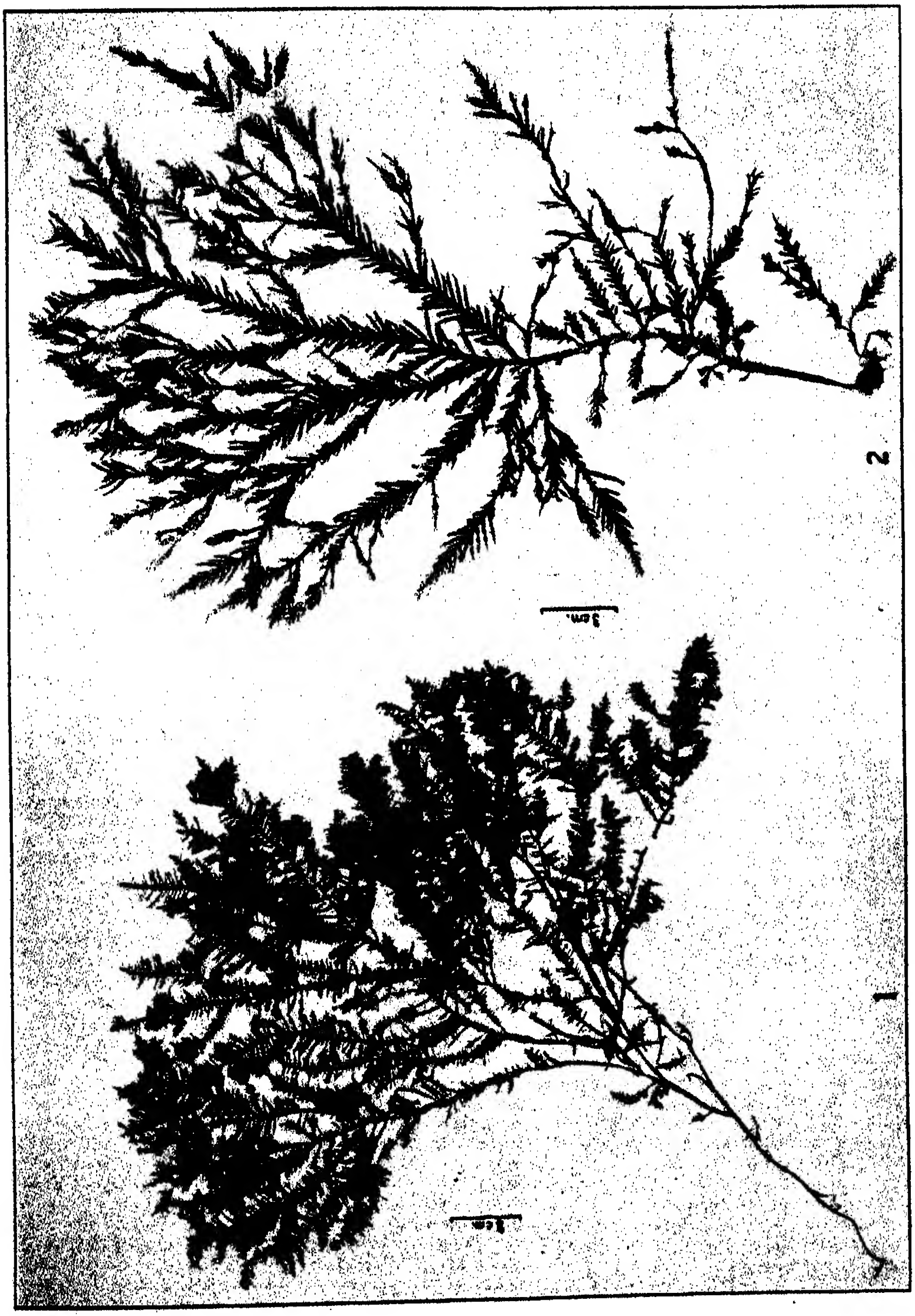
Proactinomyces spp.



Mastotermes darwiniensis Frogg. 1. Forewing; 2. Hindwing.



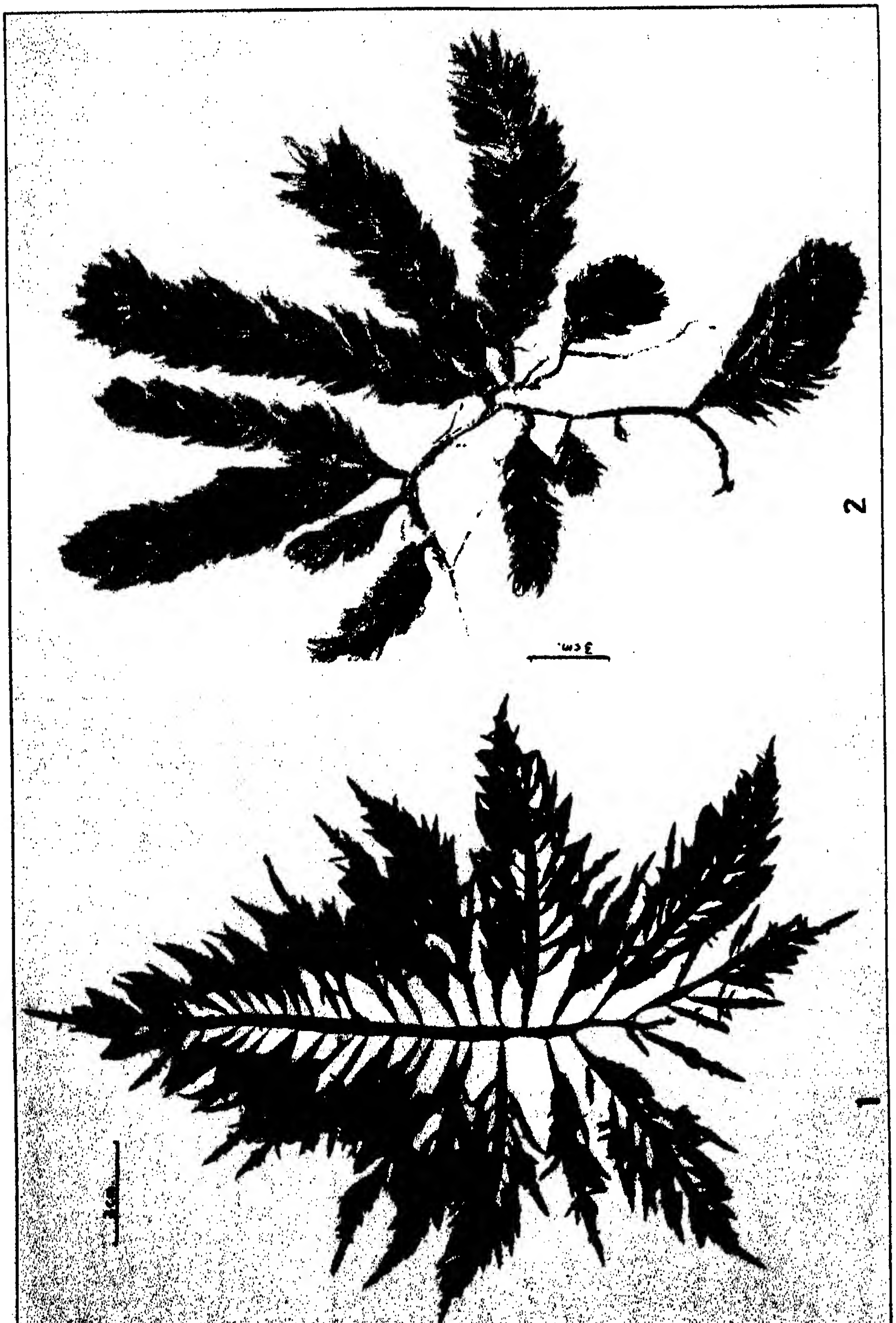
Viminaria denudata.—Pneumatophores and horizontal roots.



Gelidium rectangulare, n. sp.

Pterocladia pectinata, n. sp.

ltophyllum Perrinae, n. sp.



1. *Champia insignis*, n. sp.

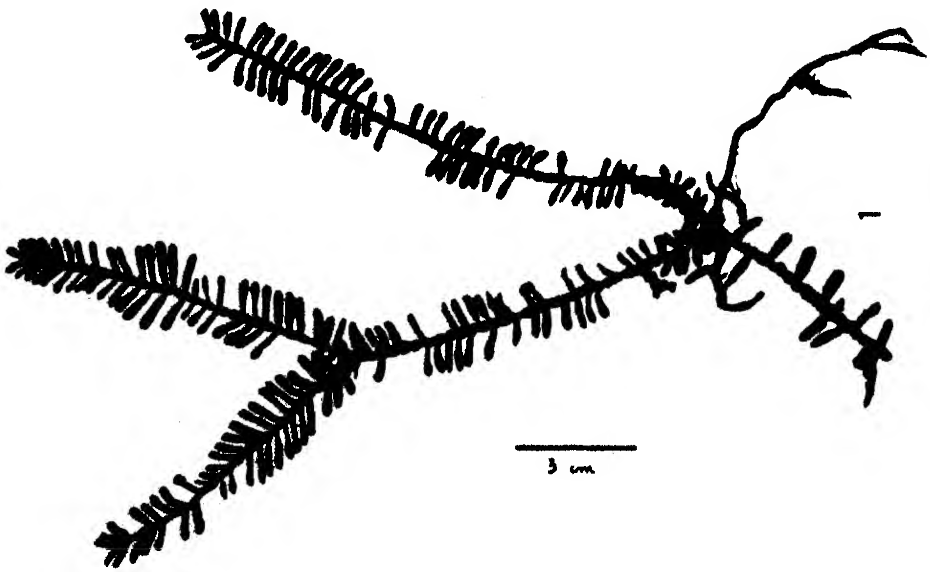
2. *Caulerpa Cliftoni* Harvey.

Dictyota alternifida J. Ag.

Dictyota bifurca J. Ag.

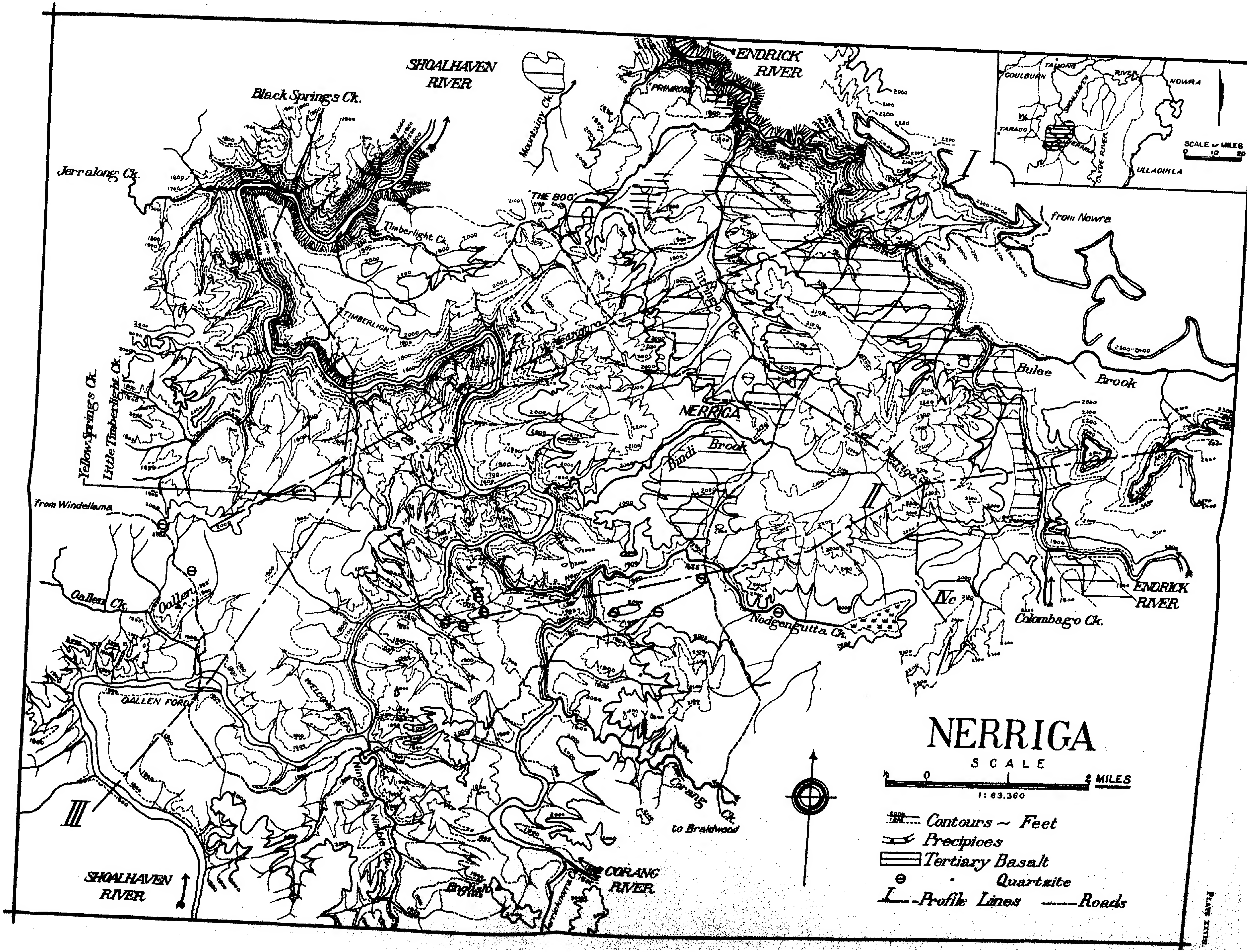
2

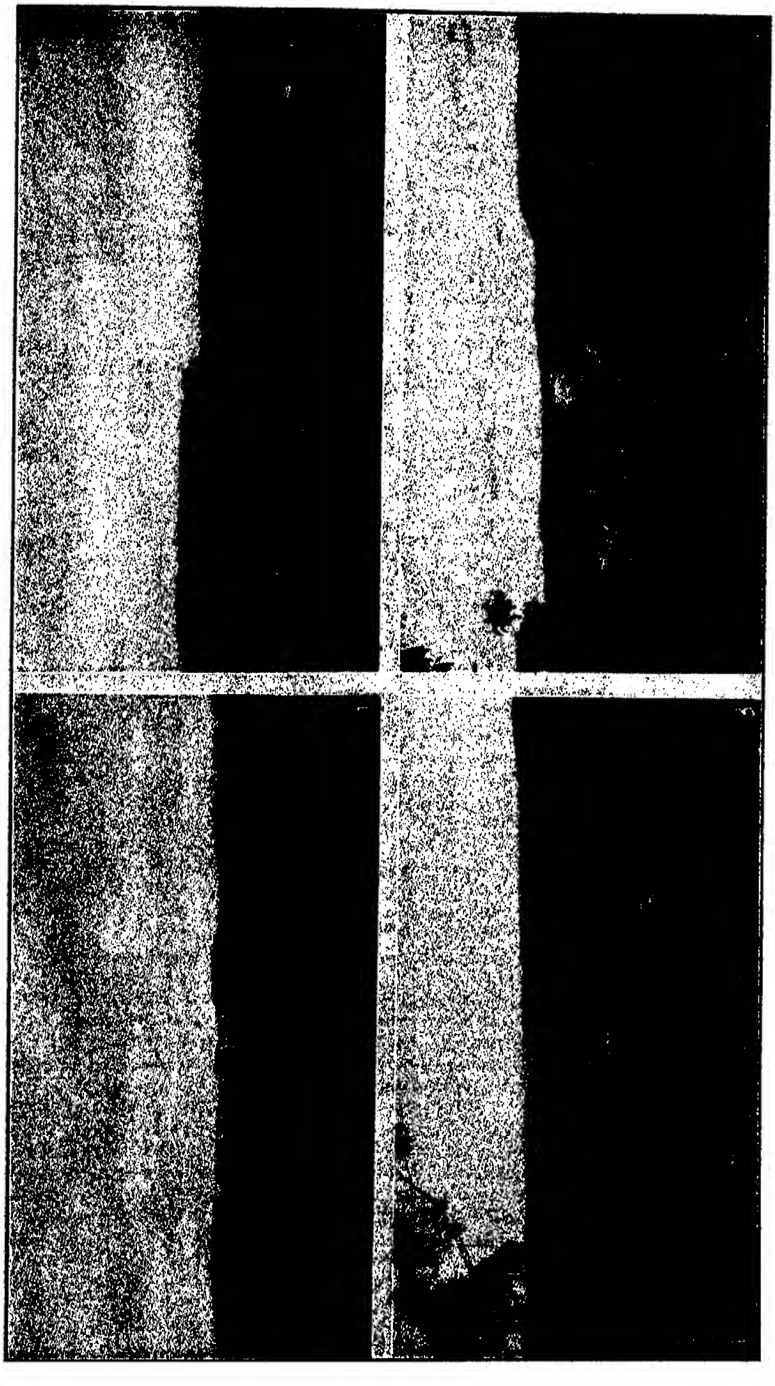
Caulerpa articulata Harvey.



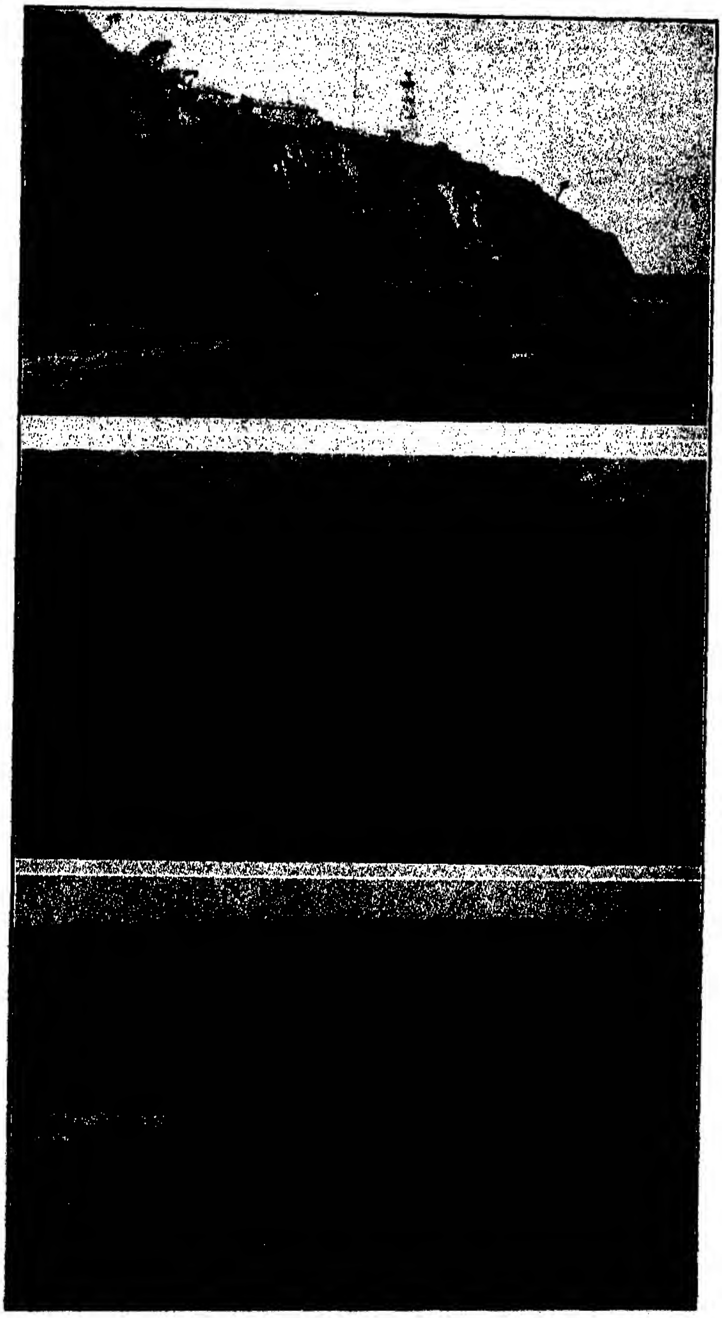
1

Caulerpa annulata. n. sp.

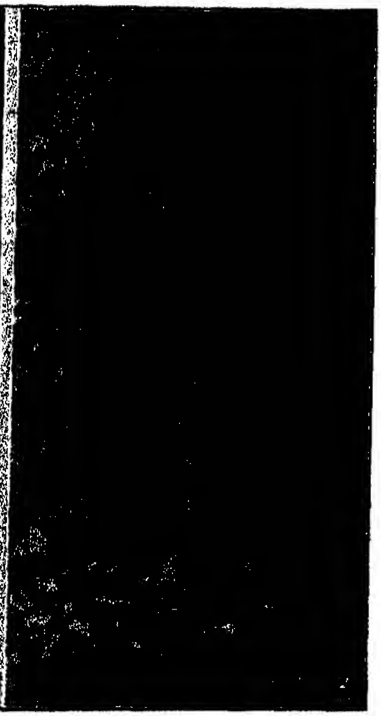

NERRIGA
SCALE
1/2 0 1 2 MILES
1: 63,360
Contours ~ Feet
Precipices
Tertiary Basalt
Quartzite
Profile Lines
Roads
SHOALHAVEN RIVER
Black Spring's Ck.
Jerralong Ck.
Mountain Ck.
"THE BOG"
Timberlight Ck.
TIMBERLIGHT
ENDRICK RIVER
PRIMROSE
from Nowra
Bulee Brook
NERRIGA
Bindi Brook
Tianjara Ck.
Nerriga Ck.
Meangora
Yellow Springs Ck.
Little Timberlight Ck.
From Windellama
Oallen Ck.
Oallen
OALLEN FORD
WELCOME REEFS
Nodgengutta Ck.
Colombago Ck.
Corang Ck.
to Braidwood
CORANG RIVER
Nimble Ck.
I
II
III
IVc
GOULBURN
TALLONG
RIVER
NOWRA
SHOALHAVEN
TARAGO
NERRIGA
CLYDE RIVER
ULLADULLA
SCALE OF MILES
0 10 20



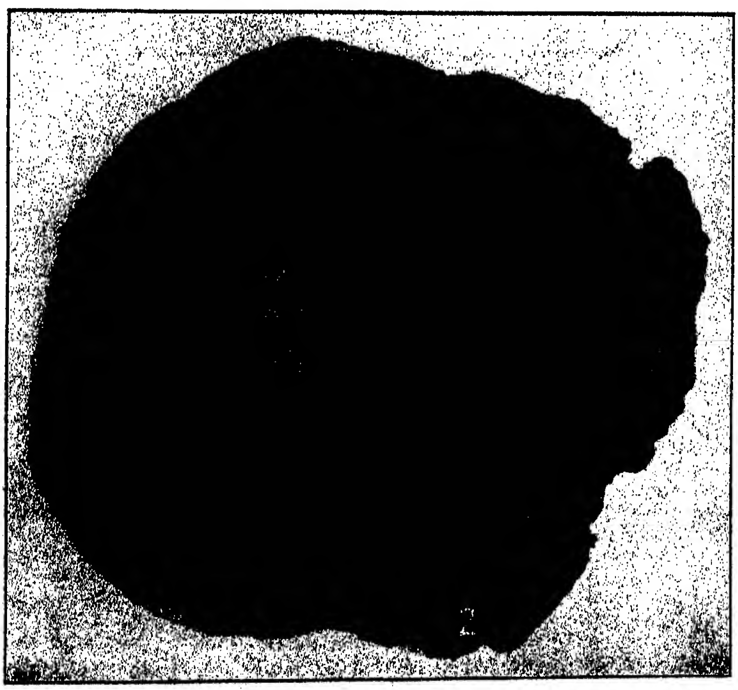
1.—View from Endrick Trig. Station. 2.—View from Corang Trig. Station. 3.—Pre-canyon valley of the Shoalhaven. 4.—Valley of Endrick River.



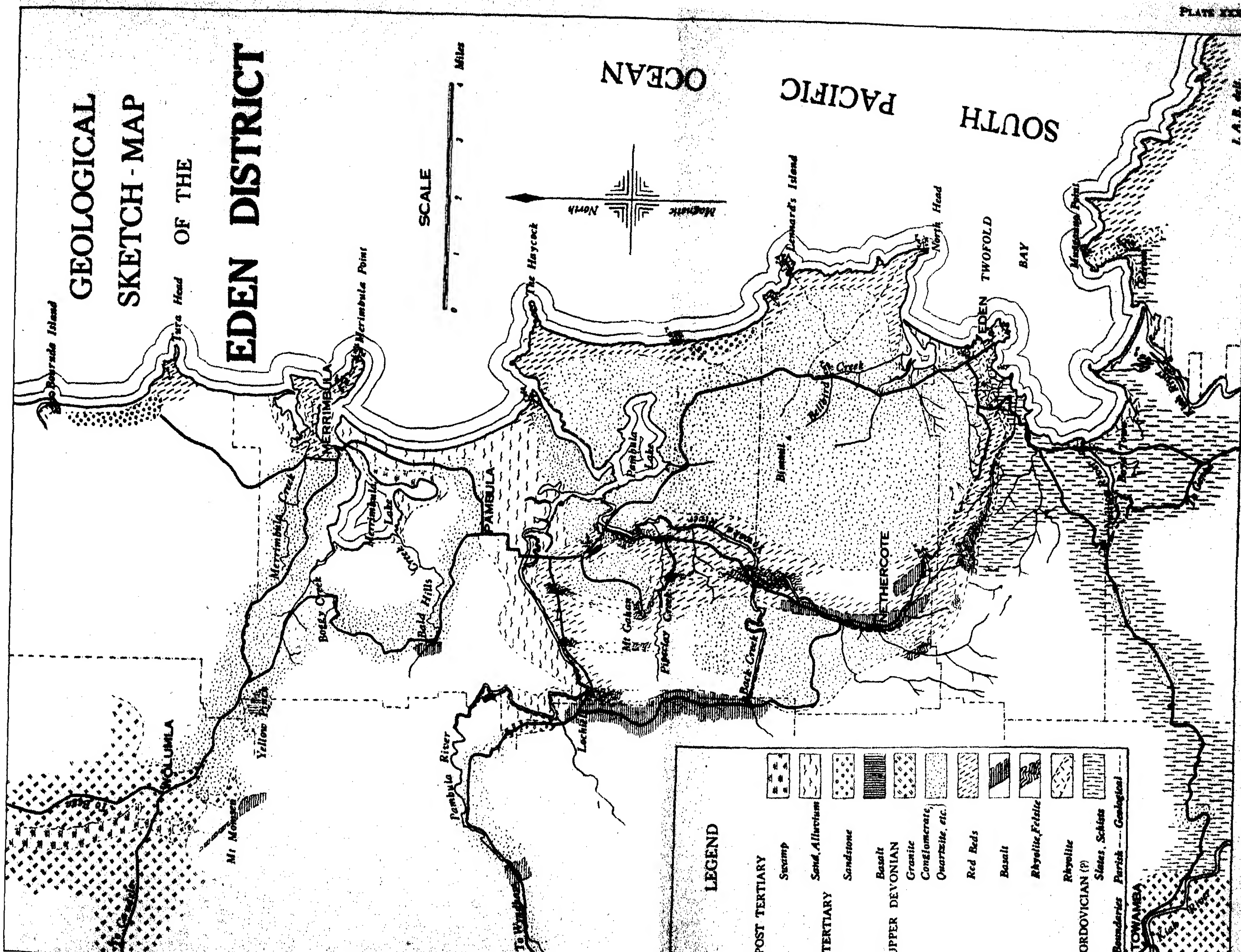
1. Junction between older Palaeozoic sediments and overlying rhyolite, Eden Lighthouse.—2. Unconformity between older Palaeozoic sediments and Upper Devonian rhyolite, north of Tathra.—3. Columnar rhyolite, south of Eden Lighthouse.

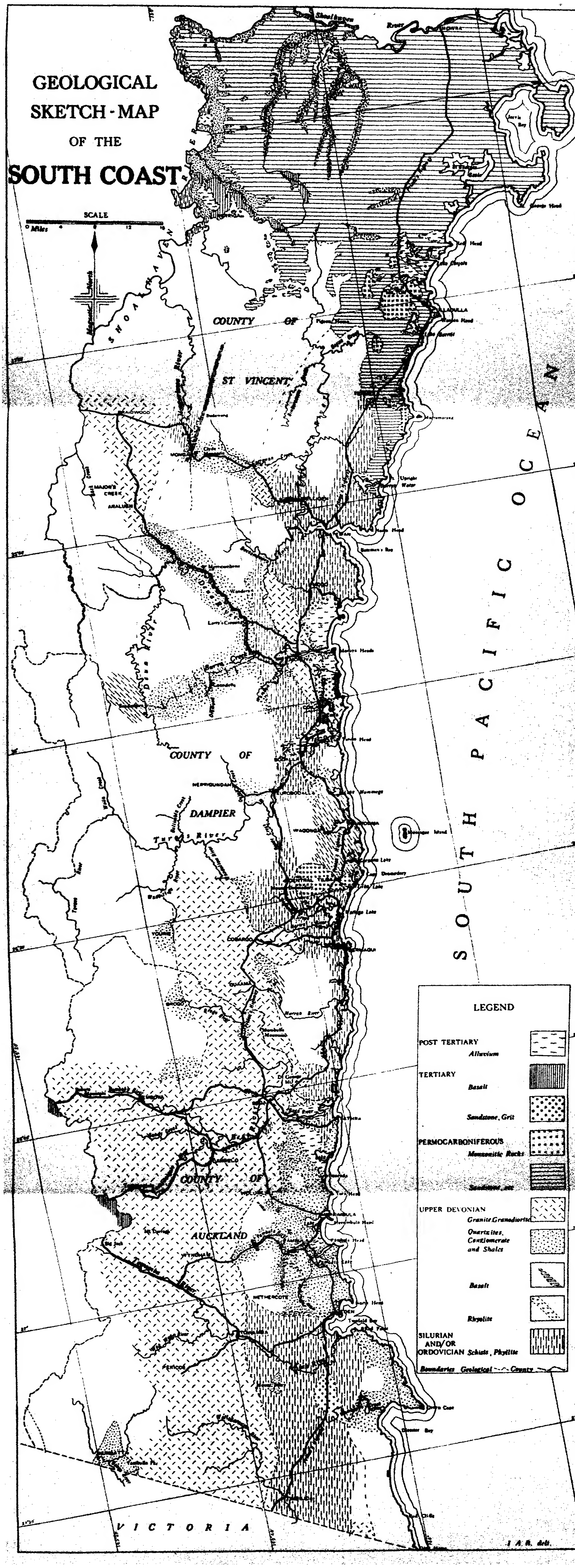


1. Eroded surface of rhyolite overlain by conglomerate at "Edrom".—
2. Red beds deposited against eroded surface of rhyolite at Eden.—
3. Ripple-marks in Upper Devonian sediments.



1.—Spherulites in rhyolite, Munganno Point.—2. Polished surface of large spherulite.


GEOLOGICAL SKETCH-MAP OF THE EDEN DISTRICT
SCALE
Miles
SOUTH PACIFIC OCEAN
Magnetic
North
Yura Head
Merrimbula Point
The Haycock
Lennard's Island
North Head
TWOFOLD BAY
EDEN
MERRIMBULA
PAMBULA
NETHERCOTE
WOLUMLA
TOWAMBA
Merrimbula Creek
Merrimbula Lake
Pambula Lake
Bald Hills
Mt Gahan
Pipeclay Creek
Back Creek
Pambula River
Yellow Pinch
LEGEND
POST TERTIARY
Swamp
Sand, Alluvium
TERTIARY
Sandstone
Basalt
UPPER DEVONIAN
Granite
Conglomerate, Quartzite, etc.
Red Beds
Basalt
Rhyolite, Felsite
Rhyolite
ORDOVICIAN (?)
Slates, Schists
Boundaries Parish --- Geological ---
I. A. B. delt.


GEOLOGICAL
SKETCH-MAP
OF THE
SOUTH COAST
SCALE
Miles
Magnetic North
SOUTH PACIFIC OCEAN
COUNTY OF ST VINCENT
COUNTY OF DAMPIER
COUNTY OF AUCKLAND
SHOALHAVEN
VICTORIA
LEGEND
POST TERTIARY
Alluvium
TERTIARY
Basalt
Sandstone, Grit
PERMOCARBONIFEROUS
Monzonitic Rocks
Sandstone, etc
UPPER DEVONIAN
Granite Granodiorite
Quartzites, Conglomerate and Shales
Basalt
Rhyolite
SILURIAN AND/OR ORDOVICIAN Schists, Phyllite
Boundaries Geological County
I. A. B. delt.

THE

PROCEEDINGS

OF THE

LINNEAN SOCIETY

OF

NEW SOUTH WALES

ANNUAL GENERAL MEETING.

WEDNESDAY, 25th MARCH, 1931.

The Fifty-sixth Annual General Meeting was held in the Society's Rooms at Science House, Gloucester Street, Sydney, on Wednesday, 25th March, 1931.

Mr. E. Cheel, President, in the Chair.

The minutes of the preceding Annual General Meeting (26th March, 1930) were read and confirmed.

PRESIDENTIAL ADDRESS.

Ladies and Gentlemen,

We meet to-night for the first time in our new quarters in Science House, Sydney. The completion of this building, with its occupation by a number of the scientific and professional societies of Sydney, will for all time mark one of the significant dates in the advance of Science in Australia. The concentration of such Societies in the one building will help to bring to the public a greater appreciation of Australian Science and of Australian scientific workers than is possible when the Societies are scattered and carry on their work in different parts of the city. There are other advantages to which the members of the Societies may look forward, amongst which will be the ease of consulting the libraries housed in the building and also the ease of gathering information from the officers and members of the different Societies. There are still scientific and professional Societies in Sydney that have not found it possible or practicable to make Science House their headquarters, but it is our hope that, before many years have passed, all the present difficulties will have been overcome and that Science House will be the home of all kindred Societies.

Science House represents the realization of the desire of many of our scientific workers, often expressed during past years. Perhaps the earliest record of the wish that we have is that voiced by the late Professor Archibald Liversidge (one of the original members of our Society) in his Presidential Address delivered to the Royal Society of New South Wales on 7th May, 1890. After expressing

his own desire that the Royal Society should have even better accommodation than it had then at 5 Elizabeth Street, he continued: "In fact what is wanted is a modest edition of Burlington House, Piccadilly, which was built by the Imperial Government, to lodge the Royal Society, the Astronomical, the Chemical, the Geological and certain other societies, together with the Royal Academy." He then further detailed his ideas of what such a building might be, and concluded: "I believe that if the matter were carried out, even as a commercial undertaking, it would prove not only a very useful but also a fairly profitable investment." We hope to be able to prove that Professor Liversidge's belief was justified.

It is a strange coincidence that your Council first resolved (21st September, 1927) that a scheme for Science House was practicable and that it was prepared to join in such a scheme, only a few days before the death of Professor Liversidge in London (26th September, 1927).

The stages in the development of the Science House scheme have been detailed by my predecessors and all I need add now is that after the Annual Meeting a year ago the building progressed steadily and satisfactorily. The foundation stone was set by His Excellency the Governor of New South Wales, Sir Philip Game, on Tuesday, 24th June, 1930. The building was practically complete by the end of January, 1931, and most of the societies were able to enter into occupation of their new offices about that time. The question of an official opening function is under consideration by the three owner-bodies. I think you will all agree with me that the building itself reflects the greatest credit on the architects (Messrs. Peddle, Thorp and Walker) and the builders (Messrs. John Grant & Sons) and is a worthy addition to the notable buildings of Sydney. It is a matter for regret that Mr. Peddle, senior partner of the firm of architects responsible for the design, who was so keenly interested in the project, did not live to see it completed.

We ourselves are becoming accustomed to the change and are beginning to reap some of the benefit of having the library once more close at hand. The task of removing the library from the Macleay Museum and rearranging it is no light one, and it will be some time before it is complete, but good progress has already been made and it is now possible to consult any reference in the library at comparatively short notice. The room in which we meet to-night is to be retained solely for our own meetings and as a reading room in which members may consult references from the library and where current additions to the library will always be available. It is hoped that members will avail themselves fully of those facilities.

An additional attraction for members of the Societies lies in the proposal, put forward by the Australian Chemical Institute, that the Societies join together for the purpose of providing a common lounge and smoke room in the building. There seems to be every prospect that this proposal will be successful and that there will be a place where members of different Societies may meet one another informally and in comfort.

During the present times of financial difficulty it is perhaps not surprising that government subsidies to scientific societies should be reduced. Our subsidy from the Government has been reduced by half, but we hope that with the return of normal conditions, our original grant will be restored.

The coming year promises to cause your Honorary Treasurer and Council some measure of anxiety. The fact that Science House was completed at a time of

financial stress has made it a difficult matter for the Council to dispose of Macleay House, 16 College Street. As the Council did not expect to encounter this difficulty, it will have to keep a close watch over finance during the year in the event of failure to dispose of Macleay House.

The Australian Expedition to the Antarctic under the leadership of Sir Douglas Mawson returned to its work for a second season, departing from Hobart early in November last. After another successful voyage, during which much new ground was explored, the *Discovery* has now returned to Australia, and we offer our congratulations and a hearty welcome to the leader and his staff.

The Australasian Association for the Advancement of Science held its twentieth meeting at Brisbane in May-June, 1930. The meeting was a highly successful one, being attended by a large number of members from the other States, and the visit of such a large gathering of scientists should provide inspiration and incentive to the scientific workers in Queensland. During the meeting the General Council of the Association resolved, on representations made from New Zealand, to alter the name to the Australian and New Zealand Association for the Advancement of Science.

The first Fletcher Memorial Lecture was delivered by Mr. A. H. S. Lucas, M.A., B.Sc., who took as his subject "Joseph James Fletcher, an Idealist Secretary", giving an intimate personal account of the late Mr. Fletcher and his work. The Council has invited Professor F. Wood Jones, of Melbourne, to deliver the Lecture in 1931.

The J. H. Maiden Memorial Shelter Pavilion, erected in the Botanic Gardens by public subscription, was dedicated on 19th May, 1930, by His Excellency the Lieutenant-Governor, Sir W. P. Cullen, the ceremony being attended by a large gathering of members of the Linnean Society and kindred organizations.

The third number of the Memorial Series containing an appreciation of the late J. H. Maiden, written by Mr. A. H. S. Lucas, has been issued.

During the year, I attended, as your representative, a meeting called by the Town Planning Association of New South Wales for the purpose of taking steps to impress upon the Government the need for securing sufficient parks and playing grounds for the future—an object worthy of our support.

The first of the Society's coloured plates of Australian wild flowers was issued with Part 4 of the PROCEEDINGS for 1930. The subject of the plate was *Epacris longiflora* and it is pleasing to be able to state that the demand for the postcards available for sale has been satisfactory. The blocks for the second of the Series (the Waratah, *Telopea speciosissima*) were practically ready for delivery in time for its issue with Part 5 of last year's PROCEEDINGS in December, but unfortunately they were destroyed in a disastrous fire which completely gutted the premises of the Society's block-makers, Messrs. A. A. Lawson, Ltd. Fresh blocks have been made and the plate will appear with Part 1 of the PROCEEDINGS for 1931.

Some progress was made during 1930 with the proposal to have set apart an area for the cultivation, preservation and exhibition of the native flora. The Committee appointed by your Council to further the project, discussed the matter with a Committee appointed by the National Park Trust. The representatives of the National Park Trust expressed themselves wholeheartedly in accord with the idea, and the Under Secretary for Lands also expressed sympathy with the project. Members of the two Committees paid a visit to National Park, accompanied by a Surveyor from the Lands Department, with the object of reconnoitring

the Waterfall end of the Park to see if it might be possible to set apart an area there for more intensive cultivation of the native flora. The result of the visit was satisfactory, but in view of the fact that funds would be needed to carry out the idea it was finally decided that it would be wise to postpone further action until a more favourable time.

In response to representations made last year by various Societies to the Department of Lands, the Minister has now approved of the proposal that a large area of land, comprising about 34,600 acres, on the watershed of the Bellingen, Nambucca and Macleay Rivers, and embracing Point Lookout, be set apart as a National Park, and action is now proceeding to have this area reserved from sale and from lease generally for Public Recreation. I take this opportunity of expressing our gratification at the result of this application and also of expressing our appreciation of the action of the Minister and the Under Secretary for Lands.

The concluding part of Volume lv of the Society's PROCEEDINGS was issued in February. The complete volume (750 plus lxxx pages, forty plates, one portrait, one coloured plate and 268 text-figures) contains thirty-five papers from twenty-seven authors. In addition to the usual variety of papers the volume contains No. 3 of the Memorial Series and the Fletcher Memorial Lecture for 1930.

Exchange relations with scientific societies and institutions were maintained at a satisfactory standard. The receipts for the year total 1,866, compared with 2,540, 1,821 and 2,084 for previous sessions. During the year the following institutions have been added to the exchange list which now numbers 223: Société de Biologie de Lettonie, Riga; Imperial Agricultural Experiment Station in Japan, Tokyo; Geologisch Bureau, Heerlen, Holland; School of Public Health and Tropical Medicine, Sydney.

Your Council discussed the small average attendance at the Society's monthly meetings and it was suggested that perhaps some hour of meeting would be more convenient to members than the present one. A questionnaire was circulated to members resident in the metropolitan district, and the replies showed that the present hour (7.30 p.m.) is the most convenient for the great majority of those members.

We were delighted to receive a visit from Professor J. T. Wilson, Honorary Member and former President, who was present at the July meeting and brought to us a message of greeting from Professor J. P. Hill, also an Honorary Member.

The vacancy on the Council caused by the resignation of Dr. A. J. Nicholson on account of his appointment to the Division of Economic Entomology at Canberra, was filled by the appointment of Dr. W. L. Waterhouse.

On behalf of members I take the opportunity of expressing our congratulations to Professor J. P. Hill on the award to him of a Linnean Medal by the Linnean Society of London; to Dr. W. L. Waterhouse on being the first to attain the degree of D.Sc.Agr. in the University of Sydney; to Dr. H. Claire Weekes, former Linnean Macleay Fellow in Zoology, on being the first woman to receive the degree of Doctor of Science in the University of Sydney; and to Dr. P. D. F. Murray, also a former Linnean Macleay Fellow in Zoology, on being awarded a Smithson Research Fellowship in Natural Science at the University of Cambridge.

Since the last Annual Meeting fifteen Ordinary Members have been added to the roll, nine have resigned, and the names of four have been removed on account of arrears of subscription.

The year has passed without the Society losing a single member by death. I should refer, however, to the death of Mr. Duncan Carson, which took place on 6th January, 1931, only a few days after his resignation from membership took effect. Mr. Carson, who was in his 71st year, was one of the oldest members of the Society, having been a member since 1890. He was one of the founders of the firm of Winchcombe, Carson, Ltd., and was a noted pastoralist, having been associated, during his lifetime, with almost every movement having as its object the benefit of the pastoral industry.

The year's work of the Society's research staff may be summarized thus:

Mr. H. L. Jensen, Macleay Bacteriologist to the Society, isolated about fifty strains of the genus *Micromonospora* and subjected them to a close study in order to obtain a basis for establishing definite species. The results of this study are embodied in a paper "The genus *Micromonospora* Ørskov, a little known Group of Soil Microorganisms" which appeared in Part 3 of the PROCEEDINGS for 1930. Further extensive studies have been made of a number of organisms which form an interesting transition between the genera *Actinomyces* and *Mycobacterium*. A group of soil actinomycetes has been studied with the object of deciding whether the sometimes suggested distinction between the genera *Actinomyces* and *Cohnistreptothrix* is justified. An old culture of an interesting cellulose-decomposing fungus brought from England was found to be alive and was subjected to fresh examination, the result of which was published as a note in Part 5 of the PROCEEDINGS for 1930. A preliminary study was also made of fungi forming mycorrhiza in *Grevillea montana*.

Miss Ida A. Brown, Linnean Macleay Fellow of the Society in Geology, spent a considerable portion of the year in an extensive study of the Monzonitic Complex of the Mount Dromedary District. This igneous complex appears to be unique in New South Wales and contains an assemblage of rare rock-types. In the paper embodying the result of this work the petrogenesis has been discussed, but several other problems have arisen from the work on Mt. Dromedary and other parts of the South Coast. Such general problems as the genetic relationships of the alkaline, monzonitic and subalkaline igneous rocks, and the relation of their development and intrusion to the geological structure and tectonic history of the associated sedimentary rocks have been considered and will form the subject of further papers.

A considerable amount of additional field work has been carried out in the coastal district between Mt. Dromedary and the Victorian Border, and the information obtained has to be compared and correlated with that of the regions previously examined.

Miss Brown proposes, during the coming year, to continue her investigation of the geology of the South Coast, dealing with problems of the geological age, conditions of sedimentation, mutual relationships and subsequent tectonic history of the sedimentary rocks, and the relationships, petrogenesis and correlation of the associated igneous rocks.

Mr. Frank A. Craft, Linnean Macleay Fellow of the Society in Geography, has carried out a series of detailed physiographical surveys of portions of the Shoalhaven River valley. The first of these covered about 70 square miles of the Tallong district, where it was found possible to trace back the evolution of the modern topography into the period preceding the late Tertiary basalt flows. Then the Bungonia district was examined and later a detailed reconnaissance

undertaken of the Nerrimunga Creek drainage system, forming part of the western valley of the Shoalhaven River.

Two short papers—"Goulburn—a vital Point on the New South Wales Highlands" and "The Topography and Water Supply of Cox's River, N.S.W."—were published in Part 4 of the PROCEEDINGS for 1930, and a third paper "The Physiography of the Shoalhaven River Valley. i. Tallong-Bungonia" will appear early in 1931.

During the coming year Mr. Craft proposes to continue work on the Shoalhaven area and to make detailed surveys in the Nerriga district; also to work on either side of the Shoalhaven, to deal with Sassafras Range on the east and the Sandhills (Gourock) Range on the west in an endeavour to determine the origin of the valley between them. He also proposes to complete a piece of work commenced in 1926, on the "Geography of the Blue Mountain District".

Two valid applications for Linnean Macleay Fellowships, 1931-32, were received in response to the Council's invitation of 24th September, 1930. I have pleasure in reminding you that the Council reappointed Miss Ida Alison Brown, B.Sc., and Mr. Frank Alfred Craft, B.Sc., to Fellowships in Geology and Geography respectively for one year from 1st March, 1931, and in wishing them a successful year's research.

As this is my last meeting in office as President, it is my privilege to offer my very best thanks to the Secretary (Dr. A. B. Walkom) for the efficient way in which he has carried out the duties connected with the meetings of the Council, as well as the general business, and the financial interests (in conjunction with the Honorary Treasurer, Dr. G. A. Waterhouse) which have been more onerous than ordinarily on account of special requirements in connection with the building of Science House. I wish also to express my thanks to Dr. Walkom for his help to me personally.

A REVIEW OF THE MYRTLE FAMILY (MYRTACEAE).

For the main part of my Address, I propose to give a brief review of the plants commonly known as "Myrtles", of which upwards of 3,000 species are now known to science, and, according to modern classification, are classified into 74 genera in the family Myrtaceae.

If we review the early history of the true "Myrtles", which must not be confused with other forms of plant life such as "Tasmanian Myrtle",[1] "Tasmanian Mountain Myrtle",[2] "Wild Myrtle",[3] "Sand Myrtle",[4] and the "Otahite Myrtle",[5] we shall find that as far back as 1735 the genus *Myrtus* was founded by Tourneforte (1770). This genus may, therefore, be regarded as the type of the family. The main characters of the family Myrtaceae are taken from the true Myrtles (*Myrtus*).

In his "Systema Naturae", Tome ii, 1770, Linnaeus classed the genus *Myrtus*, together with *Eugenia*, with the Icosandria Monogynia. Some modifications have been proposed, such as *Myrti* by Jussieu (1789), *Myrtoideae* by Ventenat (1794), *Myrteae* and *Myrtineae* by De Candolle (1826, 1828), and finally *Myrtaceae* by

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[1] *Nothofagus Cunninghamii* (Fam. Fagaceae).
[2] *Phebalium montanum* (Fam. Rutaceae).
[3] *Ruscus aculeatus* L. (Fam. Liliaceae).
[4] *Leiophyllum buxifolium* (Fam. Ericaceae).
[5] *Securingea nitida* Lindl. (Fam. Euphorbiaceae).

the celebrated Robert Brown (1866), who, in his "General Remarks Geographical and Systematical on the Botany of Terra Australis" (1866) says: "This is one of the most extensive tribes in Terra Australis; in which considerably above two hundred (200) species have already been observed, and where the order is also more strikingly modified than in any other part of the world." We must remember that Robert Brown had been accustomed to those plants which belong to the species *Myrtus communis*, found in a wild state in Europe, and this, as already stated by Woolls (1867), is supposed to have been introduced from Persia. Woolls further suggests that "there is reason to believe that during the eocene period when the climate of that division of the globe was much warmer than it is now, Myrtaceous trees flourished there with other plants of an Australian aspect".

According to Bradley, the plants commonly known as "Myrtles", which are small trees and shrubs, were introduced into Great Britain by Sir Francis Carew and Sir Walter Raleigh in 1585, when they resided in Spain and discovered the preparations for the Spanish Armada against Great Britain.

These plants became very popular in Great Britain and other parts of Europe on account of their ornamental appearance and for the aromatic oil which formed an important article of trade. It is interesting to note that as far back as 1597 Gerarde remarks that "Myrtles never bear fruit in England". Thirteen species of the genus *Myrtus* were enumerated by Linné in the third edition of the "Species Plantarum" published in 1764. Twenty-seven years later an accession of twenty-eight was made by Gmelin. Sir James Edward Smith observed (1819) "that few genera are more confused in the works of Linnaeus than that of *Myrtus*. All that properly belong to it are those that have a corolla of 5 petals with a 5-cleft calyx and a 2-celled or 3-celled berry. These characters distinguish it from *Eugenia*, *Psidium* and *Calyptranthes*." Although Linnaeus enumerated thirteen species, several of these have been removed to other genera, and especially the last, *Myrtus leucadendra* L. (Sp. Pl. 676), which was subsequently made a distinct genus by Linnaeus himself. In the "Mantissa Plantarum Generum", p. 74, is an additional *Myrtus* named *M. angustifolia* by Linné, for which see *Metrosideros*. *Myrtus brasiliensis* of Linné is *Eugenia uniflora*. In 1807 Miller and Martyn (1807) enumerated thirty-six forms of *Myrtus*, and stated that "the cultivation of the Myrtle in England is assigned in the Kew Catalogue to the year 1629, when Parkinson informs us that he had three sorts". The geographical range given for the thirty-six forms in Miller and Martyn's work is of special interest, as are also the descriptive names, such as "Broad-leaved Jew's Myrtle", "Gold-striped-leaved Orange Myrtle", "Silver-striped Nutmeg Myrtle" and several others. These names were invented for trade purposes and were apparently developed from the "Common Myrtle" (*Myrtus communis*) as a result of intensive cultivation over a long period. It is quite clear also that some of the other forms, such as "Wild Clove" (*Pimento acris*) and "Jamaica Pepper" or "All Spice" of the West Indies (*Pimento officinalis* and *Pimento officinalis* var. *longifolia*), the dried fruits of which were imported from the West Indian Islands, were not true species of the genus *Myrtus*, as recorded by the earlier botanists. These have since been transferred to the genera indicated above in brackets.

Sixteen species of *Myrtus* have been recorded for Australia. Nine of these were retained by Bentham (1866), while the other seven have been found to belong to other genera and have accordingly been transferred. Two of the Australian species of *Myrtus*, viz., *M. fragrantissima* and *M. acmenioides*, have claimed

attention on account of the aromatic oil contained in the leaves, which have been used for flavouring tea.

Next to the genus *Myrtus* we have *Psidium* (established by Linnaeus in 1737), which, on account of the fruits, commonly known as "Guava", being edible, commanded considerable attention. The species *P. guajava*, together with two varieties, var. *pomiferum* and var. *pyriferum*, are natives of South America, but have spread fairly rapidly throughout the tropics. Upwards of one hundred species have since been recorded, chiefly from the warmer climates. In 1796 the genus *Decaspermum* was established by Forster (1796). Since that time ten species have been added to the flora of the Pacific Islands and the Indian Archipelago, one extending to Queensland. The latter species is included in the genus *Nelitris* of Gaertner by Bentham (1866) with the variety *laxiflora* which, so far as can be judged, is inseparable from *Decaspermum*. The variety *laxiflora* is found chiefly in the Rockingham Bay district, and was suggested as being sufficiently distinct to rank as a species by Bentham. It may be advisable to raise this to specific rank under the name *Decaspermum laxiflora*.

The characters of Australian Myrtles have been the subject of discussion by many botanists, who have remarked that they are widely different from those of other countries. Bentham has remarked (1866) that "the fleshy-fruited genera of the Order are widely spread over the tropical regions both of the new and the old world, including many of the largest forest trees, and are in Australia almost limited to the tropics, a very few species extending into New South Wales and only one into Victoria". Woolls (1881) regarded the Myrtaceae as "the most important order, whether considered in reference to the value of its timber, the medicinal and industrial properties of the species, the general character of its inflorescence, or the utility of its berried fruits". Dr. Phil. R. Schomburgh (1875) has also drawn attention to the Myrtaceae being one of the most predominant families of the Australian flora, and remarks on the abundance of the genera and species, and diversity in soil conditions.

One of the outstanding features of the Australian vegetation is the remarkable tribe Leptospermeae, which presents a uniformity that makes it easy of general recognition wherever seen, and yet the diversity is multitudinous. It is extremely adaptable, and one or more species are found in every plant community. Even in the rain-forest areas, different forms or species of the Leptospermeae are found associated with the plants of the marsh-lands as well as with those of the deep shady alluvial flats and gullies and on the top of the mountain ranges. There are very few plant communities that are not favourable to one or more species of the Leptospermeae section of the Myrtaceae. They attain to a considerable size, as pointed out by Mr. W. D. Francis (1922) as follows: "'Scrub Box' (*Tristania conferta*) and some species of *Eucalyptus* such as 'Messmate' (*Eucalyptus Cloeziana*) and the 'Flooded Gum' (*Eucalyptus saligna*), when growing in the luxuriant rain-forest sometimes exceed six feet in barrel diameter. The Eucalypts which sometimes grow in the rain-forests or on their margins often exceed the true rain-forest trees in height, but they do not grow beyond 200 feet in height, so far as the writer is aware."

Many of the species are extremely hardy, as they are capable of resisting the severest drought, as well as defying the bush-fires, and on the other hand certain species of the genera *Eucalyptus*, *Melaleuca*, *Leptospermum*, *Callistemon*, are quite happy with their feet, so to speak, constantly in water.

W. J. Stephens at the Annual General Meeting in January, 1879 (PROCEEDINGS, iii, 1878 (1879), p. 425), stated that: "The Australian flora is, as a whole, endemic or indigenous, that is to say, it presents quite a peculiar and unmistakable Australian type. But it is subdivided into two, Eastern and Western, Provinces, which differ almost in every detail, though their general characters are the same. Secondly, the Australian flora has radiated to some extent into the neighbouring Malayan and Melanesian districts by various members (for example) of the Eucalypts, Epacrids and Leafless Acacias. Thirdly, Northern Australia from Arnheim's Land eastwards has submitted to a certain degree to the influence of immigration from south-eastern Asia and India. Fourthly, the alpine flora of south-eastern Australia and Tasmania may be traced through New Zealand to the southern extremity of the American Continent and so up the chain of the Andes, which seems to have served as a bridge by which a few species of plants from the North Temperate or Sub-Arctic Zone have been introduced into this region. Lastly, the relation with South Africa."

The genus *Eugenia* was founded by Micheli in 1735. The fruits of several species are large and edible, and, as a consequence, have attracted considerable attention, so much so that several species such as the "Brazilian Cherry" (*E. uniflora*), "Rose Apple" (*E. jambos*), "Star Apple" or "Jamrool" (*E. alba*), "Kavika" or "Malay Apple" (*E. malaccensis*) and "Red Star Apple" (*E. aquea*) and many others have been cultivated fairly extensively in the tropics. In Australia we have the "Endeavour River Pear" (*E. eucalyptoides*) and "Oloorgo" (*E. suborbicularis*) and "White Apple" (*E. grandis*) which are said to be edible, and about fifteen other species, including the well-known "Brush Cherry" (*E. myrtifolia*) and "Lilli-pilli" (*E. Smithii*), extending to the Victorian border. About thirteen hundred species of this genus have been described, most of which are spread throughout the rich fertile valleys of the tropical areas of Australia and Asia.

Mr. E. C. Andrews (1916) states that "the *Eugenias* and allied genera, such as *Myrcia*, *Calyptranthes*, *Marlieria* and other types, are widely spread and suggest former direct land connections between all the great land blocks, this older interchange of fertile types in regions of mild and moist climate, however, having ceased long since".

Myrtles in Commerce.

I make no apology for introducing into this Address the part played by the Myrtle family in the world of commerce. The connection of the botanist with the industrial world, as well as in general commercial activities, is very far reaching, for we find that, although the mineralogist or geologist may be able to guide the commercial citizen in regard to the sources of supplies of coal and various kinds of minerals which enter so much into modern methods of industries, and that the zoologist may be able to aid citizens in regard to the supplies of hides and skins for fur clothing and boot-leather, the botanist is called upon for information concerning the plants which yield the best quality and highest percentage of tanning materials, such as is obtained from our Wattles, Mangroves and Eucalypts, and even the source of supplies of Essential Oils, Fatty Oils, Rubber, Flax, Hemp and numerous other fibre materials, as well as drugs utilized in medicines, etc., and the numerous forms of fruit, vegetables and grain-producing plants which enter into our everyday food supplies.

We cannot claim to have any historic gardens in the Commonwealth of Australia, such as the Physic Garden of John Gerard in Holborn and the Apothecaries Garden at Chelsea near London, but we have vast supplies of raw materials in nature, and valuable data concerning them published in the Proceedings of this and other scientific Societies during the past fifty-five (55) years, and the valuable collection of samples brought together by botanists and preserved in the various herbaria which are the standards of comparison for future generations, and thus form a most valuable asset to the community. These collections are of special interest to economic biologists who are conducting an important work on behalf of the citizens of every State.

We owe a deep debt of gratitude to the late Baron Ferdinand von Mueller, who, I think we can safely say, was the first to recognize the excellent qualities of the Eucalypts. He was instrumental in forwarding seeds all over the world and in initiating plantations, especially in swampy areas in Europe, Algeria, Transvaal, India, New Zealand, California, South America, Cape Colony, Mexico and many other countries, generally with the result, as at the Campagna at Rome, of considerably ameliorating climatic conditions, reclaiming unhealthy areas, or supplementing timber supplies. As a result of the Baron's foresight, our Australian Eucalypts are playing a very prominent part for all time to come in the sylvan culture of vast tracts of land amounting to millions of acres of Eucalypts in various parts of the globe within the warmer zones.

The exportation of Eucalyptus seeds, even in the 'sixties, assumed some magnitude. The monthly mails conveyed parcels of seeds to the value of over £100. In 1861 upwards of 51,000 packets of seeds and 31,455 plants of Australian trees and shrubs (chiefly *Eucalyptus* and *Acacias*) were distributed to settlers in South Africa. The interest in Australian plants is still keen, for the records of the Botanic Gardens and National Herbarium in Sydney show that during the past four years upwards of 460 lb. of seeds of Australian plants have been despatched to the Union of South Africa, to the value of £500.

The most popular species in demand is *Eucalyptus Maideni*, of which 157 lb. of seeds were despatched; there follow in popularity *Eucalyptus gigantea*, with 55 lb., several species with 50 lb., and others with 10 lb. It will thus be seen that the Myrtle family of Australia is intensely popular in other countries, which accounts for so many works being published upon the utility and industrial uses of the various species belonging to the great family of Myrtaceae, by such writers as Monsieur Prosper Ramel of Paris, Ricardo Platzech Coptonas of the Argentine Republic, and Professor Ellwood Cooper of California in years gone by, and more recently "A Reconnaissance of the Forest Trees of Australia from the Point of View of their Cultivation in South Africa" (1926) by C. C. Robertson, and "Eucalypts in New Zealand" (1927) by J. H. Simmonds.

Tannin Products.

It has long been known that certain species of our Australian Wattles, notably *Acacia pycnantha* and *Acacia mollissima*, are rich in tannin, and during recent years the "Red Gum" (*Eucalyptus rostrata*) and "Mallet Bark" (*Eucalyptus astringens*) have received considerable attention. "Mallet Bark" was exported in 1906 to the extent of 155,000 tons per annum, but dropped to 5,000 tons in 1920. It occurs over a comparatively narrow strip of country on the west side of York-

Albany line in Western Australia. Whilst the value of the exports in 1905 amounted to £154,087, there has been a further decline during recent years, for we find that in 1927-28 the exports amounted to £27,662, a drop of £126,425. The cause of the decline in the output of this bark was the indiscriminate destruction of the Mallet forests, which took place when the value of the bark became known. Other species of Eucalypts have been used as substitutes or mixtures, such as "White Mallet" (*E. falcata* var. *ecostata*), "Blue Mallet" (*E. Gardneri*), "Swamp Mallet" (*E. spathulata*), "Karri" (*E. diversifolia*), "Gimlet" (*E. salubris*) and "Ridge Gum" or "Mountain Gum" of Queensland (*E. alba*) which extends to Java, where it is known as "River Gum".

It is the province of scientists to explore the country and through the co-operative efforts of the botanists, geologists and chemists, a remarkable amount of magnificent research work has been achieved, with the result that we have on record in our scientific literature numerous articles by such eminent authorities as Dr. Joseph Lauterer (1896), who has remarked that "the tan-resin gums are entirely endemic to Australia, and that no plants of other countries yield an exudation similar to them in chemical composition". The late Mr. J. H. Maiden, as well as H. G. Smith, has also repeatedly drawn attention to the usefulness of our Australian plants, such as the various species of *Eucalyptus* enumerated above, together with many other species of the same genus, and the *Angophoras* and Turpentine (*Syncarpia*) which yield kino and other resinoid substances which are of more or less commercial interest. Indeed, it has been suggested that "Peebeen" (*Syncarpia Hillii* of Bailey), a Queensland species of Myrtaceae, yields a resin-like substance which can be used for the same purpose as Strassburg turpentine.

In view of the above, it must occur to us all that we have not made the best of our resources. Whilst the various scientific societies, with their limited membership and funds at their disposal, have done a noble work for the British Empire, the vast population have received the benefits of such research work, but have not risen to the occasion to see that the right class of citizen was engaged to raise seedlings and replace the millions of plants that have been destroyed in the exploitation of these raw products. Much of the wealth of Australia has been obtained by the exploitation of our Australian plants. The time for further exploitation is drawing to a close. It will then be necessary to establish an effective system of selecting parent plants for the purpose of collecting seeds for the re-establishment of sufficiently large areas for utilization in the various industries. Only the fringe of the possibilities of the Myrtaceous plants has been investigated. When the resources of the Commonwealth have been properly tapped and the innate virtues of the numerous species have been exploited on proper scientific lines, our wealth-producing abilities will have been immensely increased and depression lifted. It can only be achieved by working on broad scientific principles which, when properly applied to any branch of industry, must ultimately prove to be of immense value to the community.

Myrtles in Bee-farming.

Practically all of the species of the Myrtaceae are useful bee-plants. The flowers of each individual plant of the various species are produced in great profusion and yield nectar very freely. It is said that many species of the Myrtle family seem to be much favoured by the bees and that, so far as the vegetation

of Australia is concerned, we have nothing to fear in the way of poisonous honey, as is the case of honey produced from certain plants in the neighbourhood of Trebizand on the shores of the Black Sea, which was referred to by Rev. Dr. W. W. Woolls (1867). The term "Honey Myrtles" is applied to a large number of species of the genus *Melaleuca* and other genera in Western Australia on account of the rich flow of honey obtained from the plants, and although the honey obtained from certain species of "Tea-tree" (*Leptospermum*) is said to have a rank flavour, it can be utilized in the manufacture of certain grades of tobacco.

Paper Pulp.

Australian Eucalypts have been tested for their wood pulping qualities with fairly satisfactory results. The most promising species so far are the "Karri" (*E. diversicolor*) and "Jarrah" (*E. marginata*) of Western Australia, and the "Red Mountain Ash" of Victoria (*E. gigantea*), together with "Red Stringybark" (*E. macrorrhyncha*), "White Ash" (*E. fraxinoides*), "Giant Gum" (*E. regnans*) and "Ribbon Gum" (*E. oreades*).

Other Products.

In the field of forest products we may look forward to other industries being established on much larger lines than they are at present, such as the production of charcoal, tar, wood vinegar, wood spirit and potash. Much has been written concerning the so-called "Manna" of Eucalypts, but this is in reality "Mannite", which is produced by the aid of various species of insects.

Eucalyptus macrorrhyncha, popularly known as "Red Stringybark", although only yielding 2 lb. 12 oz. of oil per 1,000 lb. of leaves, was regarded as one of the gems of scientific research on account of the new yellow dye-material called Myrticolorin, which gives colours when mordanted resembling those obtained with the better qualities of flavin, and decidedly purer than those given by quercitron bark itself or with fustic. It has been tested by Prof. Hummell of Leeds College (England) and Mr. A. G. Perkins, and the results obtained by those gentlemen were highly satisfactory. As enormous quantities of North American flavin are used in the European markets, and as Myrticolorin is about the only other known substance which can seriously rival it, the value given to "Red Stringybark" becomes at once apparent. Eudesmol is also procurable from the leaves of *E. macrorrhyncha*.

Timber Resources.

Although steel girders and a number of known metals are entering into keen competition with timber in the building of homes for our people, warehouses, factories, bridges and ships, timber is entering more and more into the service of man, and is therefore regarded as one of the most important commercial commodities in daily use. In years gone by we had vast supplies of beautiful Cedar, Hoop-pine, Coachwood and Maple. These are generally considered to be among the very best of our Australian light woods and can hold their own with any other light wood in any part of the world. Our hardwoods, such as Ironbarks, Tallowwood, Jarrah, Karri, Blackbutt, Forest Mahogany, Turpentine, and many other species of the Myrtle family, have been exploited because they are considered to be the finest and most durable timbers on the market. Some of our

Eucalypts are also regarded as par excellence in cabinet and joinery work, and such species as the "Southern Mountain Ash" (*Eucalyptus delegatensis*) and "Giant Gum" (*Eucalyptus regnans*), have been tested and proved to have superior qualities of strength, screw tests and weight resistance, and are but little heavier in cubic foot weight than the imported "Oregon". It is for this reason that timber trees of Australia have been exploited so much that in the early days of settlement timber was practically the only export from Western Australia. Statistics showed that no less a sum than £31,000,000 has been realized in Western Australia alone from the exploitation of timber. Each year greater inroads are being made into the hearts of our forests for the purpose of supplying the wants of the timber trade. Nature has been lavish in the past, but she cannot stand man's interference and wanton destruction indefinitely. The Forestry Commissions of this and other States of the Commonwealth of Australia have admitted in their annual reports that they are faced with the fact that, after a long period of exploitation, the aspect of forestry is now showing the full effect of lack of forestry management in the past, in that many areas are almost unproductive and yield an extremely small revenue per acre. It is also admitted that "the standing value of timber has been reduced to a low level and even a well stocked forest yields a comparatively low return". We know that forestry and the timber trade are more or less dependent on one another and must, in the end, stand or fall together. It is, therefore, our bounden duty to try and rescue this important industry so as to prevent it from drifting into obscurity.

Our vision seems to have been rather obscured as to the necessity of preserving and improving our timber industries. The same thing seems to have happened throughout the world, and the people have cut down timber regardless of the future and without making provision for reafforestation or regeneration.

The wholesale destruction of our forests, which are composed of Eucalypts and other Myrtaceous plants, which form four-fifths of the vegetation, arises from many causes, such as the ravages of opossums, insects and fungi, as well as the menace of parasitic Mistletoes or the unusual prevalence of storms and floods. The most drastic destruction, however, is caused more frequently through the process of girdling or so-called ringbarking. This latter is done chiefly for the utilization of land for grazing purposes. In parts of this and other States, almost complete denudation of timber resources has occurred. Fortunately, it is not too late to urge the necessity of preserving those areas that are still left, and thus prevent further destruction of timber.

What we really want is a forest conscience instilled into the mind of every citizen. The public should be taught, by every possible means, a proper realization of the value of many of our native trees and shrubs, and that one great advantage of our so-called "Gum Tree" is that in twenty-five years a tree will yield timber as large in bulk as that of a European or American Oak 350 years old. In view of this statement, made by certain authorities who have an unbiased mind concerning our timber products, we should make a special effort to preserve the parent-trees of our future forests. We should also encourage the use of our native timbers for our own requirements, which are admitted to be amongst the finest timbers procurable. This would not only create more work for our unemployed, but, in addition, would assist in re-establishing our forest areas, beautify the landscape, prevent erosion, protect our water supplies, and otherwise

improve the whole countryside from its present-day appearance of hillsides with bare rocks and alluvial valleys filled with gravel and littered with waste.

Just as forests have been created by Nature, so can forests be built up by man. It is rank fallacy to think that Nature, if left to herself, will do all that is required. Nature is certainly our best guide, and she will rebuild forests in the course of time, but it will be a long time. She will cover vast areas with some sort of vegetation, but probably not the kind we require. We cannot afford to leave the rehabilitation of our forests to the slow processes of Nature. The planting of specimen trees is one thing, the laying-out of avenues or grounds or public parks for aesthetic purposes is another—each of these has a value of its own.

We must never forget, however, the example set by those far-seeing scientists in other lands, who have not only visualized the beauties of our Australian Myrtles, but, in addition, have recognized the importance of the various species of *Eucalyptus* from a utilitarian point of view. At the present day, perhaps, no trees are grown more freely or to a greater extent over the globe for re-afforestation purposes on bare and denuded tracts of land than the different species of *Eucalyptus*. Dr. Sutherland, Surveyor-General, in his report of the Natal Government, dated 28th May, 1883, among other matters, stated that in 1834 there were but three individual trees of *Eucalyptus* at the Cape of Good Hope. At the British Empire Conference held in 1928 a statement was made that in South Africa a certain amount of *Eucalyptus* timber (largely from old trees scattered on farms) is sawn up on the gold mines to give rough planking, tram sleepers, etc., while moderate quantities of wood of *Acacia mollissima* (Family Leguminosae) and of immature *Eucalyptus* (especially *E. saligna* or *E. grandis*) are sawn up to give wood for boxes, crates, etc. To a limited extent *Acacia mollissima* and some *Eucalyptus* (especially *E. diversicolor*) are split into billets for turning into pick-handles, yokes, etc. Several other species, including *E. maculata*, *E. paniculata*, *E. resinifera*, *E. Maideni*, *E. globulus*, *E. sideroxylon*, *E. rostrata*, and *E. viminalis* are also referred to and reported on favourably by more recent authors.

From time to time International Exhibitions have been held and magnificent collections of Australian hardwood timbers have been displayed, with the result that the hardness of some of the woods has been favourably commented upon, and several metropolitan districts in Great Britain have selected the Western Australian "Jarrah" (*E. marginata*) as a suitable material for wood paving roadways.

The "Tasmanian Blue Gum" (*E. globulus*), together with "Maiden's Gum" (*E. Maideni*), *E. bicostata*, *E. St. Johnii* and *E. Mortoniana*, all of which are mere derivatives from one species, have been cultivated fairly extensively in California, as well as in South Africa and the Nilgiri Mountains in South India. This appears to be the fastest growing tree that can be planted, and is preferred when a large bulk of coarse timber is sought. It is reported that in good growth it has grown up to ten feet per year during the early years of development. When we read such statements as that published by Mr. Eric Walther (1924): "Of Californian cultivated trees the most striking are easily the species of Eucalyptus. Their towering serried ranks dominate the landscape and lend it an unique exotic flavour totally lacking in other parts of the United States of America", we can feel quite proud of our Australian Eucalypts.

Ornamental Characters of Myrtles.

No country can produce a greater number of endemic trees and shrubs belonging to one family with such wonderful coloration as is seen in the trunks, branches,

foliage and floral structure of the various species of *Eucalyptus, Eugenia, Melaleuca, Leptospermum, Callistemon, Darwinia, Chamaelaucium, Metrosideros, Verticordia, Calythrix, Regelia, Agonis*, and numerous other genera of the Australian Myrtaceae. The splendid shades of milky-white, bluish-white, ashy-grey, slaty-grey, blue, browns, pink and vinous-reds of the trunks and branches of so many species mingled with the atro-cyaneous and blue-green foliage of certain species are a great contrast to the light and dark shades of green in others. Then again, we have the unique markings of a mottled character with various shades of distinctive colour effects when the shedding of the bark occurs, which gives a characteristic tone and charm to the Australian vegetation.

Many species are gorgeous in the coloration of the flowers, while others have a sweet, delicate array of blossoms which lends a charm and makes them eminently suitable for floricultural purposes. Some of the Eucalypts and Eugenias, as well as several species of *Melaleuca, Tristania, Syncarpia, Metrosideros* and others, produce a wealth of foliage which affords a grateful shade to man and beast.

It is because of the beautiful coloration and form of the floral characters, as well as the ornamental characters of the branches and foliage, that so many writers have endeavoured to show the need for tree-planting and tree-preservation in various parts of the Commonwealth. It has been strongly urged that the natural flora of any country is the most suitable to the natural conditions of that country, that is, conditions under which little or no artificial means of culture, such as an abundance of water and manure, are available. The drought conditions do not affect the native plants in the same way as they do those of other countries. It is for this reason that we should encourage the plant breeders to apply their skill to the possible plasticity of the floral characters of the Australian Myrtles, as well as the possibilities of some species as stocks for budding and grafting those species of commercial importance. We know, for example, that it is difficult to obtain viable seeds of *Backhousia citriodora*, which is recognized as one of the world's best lemon-scented oil plants. In view of this, it is difficult to obtain large supplies of plants for extensive cultivation. It has been found, however, that *Backhousia myrtifolia* is a suitable stock for grafting and as this species sets an abundance of seeds, there is a demand for the seed supply by certain firms in the New Hebrides, who hope to be able to increase their stocks of supply by propagating *B. citriodora* by this method. There is no doubt that many of our Australian plants could be used as stocks for closely related species used in commerce. Some could be used for drought conditions, others could be used as frost resisters in the colder districts, while still others could be used as disease-resistant stocks.

Australia, like other countries, is subjected to strong winds, sometimes of a hurricane nature, and as a result fruit-crops suffer on account of the lack of protection. A careful selection of Australian plants could be made which may be eminently suitable for this purpose. Already one or more species of the Myrtle family has been successfully grown as a hedge-plant, viz., *Leptospermum laevigata*, which is commonly known as "Australian Myrtle" in South Africa, where it is regarded as the most favoured hedge for garden purposes. It is said that "None other is so neat or so graceful when kept closely clipped, though it never forms an impenetrable fence like certain other plants used for live fences or hedges. It seeds profusely and is completely naturalised in the Government Plantations in the Cape Colony Flats" (Hutchins, 1899).

Taxonomic Problems and Stability of Nomenclature.

Dr. A. W. Hill, Director of the Royal Botanic Gardens, Kew, England, in his Presidential Address to Section K—Botany, at the British Association for the Advancement of Science, 1930, has pointed out that the taxonomist of the present day is faced by many problems connected with the nature of his units and how they are bounded. He realizes that the making of many species "is a weariness to the flesh" and that, especially when it is done with a narrow outlook, it is a "hindrance rather than a help to progress".

Many botanists are in accord with the above. Some may also agree with Dr. Hill's further statement "that the taxonomic millstone around the necks of systematists is weighing heavy". Just how we can overcome this difficulty is another matter. Many of the former systematists have made the same complaints. Even as far back as 1864, Mueller, in a letter to Bentham, complained of too many species. Bentham in his reply to Mueller wrote: ". . . botanists of as great or greater experience than myself, and on whose judgment I place the greatest reliance, think that I unite too many species, and they may be right, too. All I can do is to act to the best of my judgment, fully admitting its great fallibility."

The phenomenon termed "Variation" is one which for a considerable time has engaged the attention of very eminent scientists, as well as professional gardeners. Botanists are guided by the principles, rules and recommendations laid down at the International Botanical Congress of Vienna in 1905, and extended at Brussels in 1910, and more recently at London in 1930. Some of the rules laid down have very far-reaching effects, especially when new biological facts become known which necessitate the names of certain plants being corrected. In such cases, through the changing of taxonomic systems, the stability of nomenclature is affected, and although such changes in names may be of merely academic importance in the case of floras, they may be of direct and far-reaching significance when they pertain to species which may be the source of important drugs and other forms of products in which large financial interests are concerned.

In the realm of systematic botany, which, in its widest sense, is of paramount importance, since it provides a ready nomenclature, without which the science of botany cannot advance, an attempt is made to arrange the members or units of the vegetable kingdom in strict botanical sequence, and thus make known the richness of our botanical resources. Differences of opinions and of practice among botanists in regard to plant-names, as well as personal judgment as to what constitutes a sufficient difference between two groups of related plants, are some of the causes of confusion in botanical nomenclature. A very considerable amount of confusion and indecision still exists in regard to many species. There are very few students of Nature who would venture to specify the absolute differences between a species, a race, and a variety or form. It is, in each case, a question of nice appreciation, which must vary with the constitution of every mind, and one must have a strong conviction to set up one's own opinion against that of the majority of experienced taxonomists.

Actually, a species should comprise all individual plants that resemble each other sufficiently to make us conclude that they have all descended from a common parent. A variety, however, is merely "a modification of a species".

It is generally recognized by students of the Australian flora that the genus *Eucalyptus* presents interminable difficulties in connection with the classification of its innumerable forms into anything like a natural system. Even as far back as 1866 there was difficulty in distinguishing one species from another, as will be

seen from the following remarks made by Robert Brown (1866): "Mr. Caley has observed within the limits of the colony of Port Jackson nearly 50 species of Eucalyptus, most of which are distinguished, and have proper names applied to them by the native inhabitants who, from differences in the colour, texture and scaling of the bark, and in the ramification and general appearance of these trees, more readily distinguish them than botanists have as yet been able to do."

It is interesting to note that in the same year in which the above statement was published the third volume of "Flora Australiensis" was completed by George Bentham, in which all the known forms of *Eucalyptus* were enumerated, which had reached to the total of 300 species. Of this number 135 were accepted by Bentham (who was ably assisted by Baron Ferdinand von Mueller) as valid species. Since that time there has been a great impetus in the study of this important genus. Scarcely a year passes which does not witness the publication of new "species" or "varieties" which are considered by their authors as deserving distinctive names because the plants show a few slight differences, very often only minor ones, from allied forms, so that to-day there are no less than 1,095 species and varieties described in various scattered publications.

Botanists are greatly indebted to the late J. H. Maiden for his life's work in trying to unravel the tangle in connection with the synonymy of many of the supposed species, the results of which he has compiled in his "Critical Revision of the Genus Eucalyptus". Whether we can accept the results of the decisions arrived at is entirely another matter. There are probably no plants more variable than Eucalypts, and it is perhaps not too much to say that no two trees of the same "species" are quite alike in all the technical characters relied upon by Eucalyptologists for making their diagnosis. In the case of many micro-species, it is found on investigation that authentic specimens collected or named by the authors themselves neither agree with the original descriptions nor with one another. If the creation of the new names continues at the present rate and according to the present system, the time will soon arrive when it will be impossible to say of any member of the genus that it is a Eucalypt. To make a determination and to give a binomial will become the work of a few specialists, and there need be little hesitation in predicting that no two specialists will agree.

Differences are, in many instances, artificial. In such circumstances it is necessary to decide what are really important and what are unimportant differences. The external morphological characters, and particularly the size and shape of the buds and fruits, are frequently inadequate to enable one to arrive at a definite decision, because of the uncertainty of maturity. The collectors in many instances give no particulars as to whether the material has been collected from a sapling or a fully developed tree. As a consequence of this, many of the descriptions of species of the Leptospermoideae, in which are included *Eucalyptus*, *Leptospermum*, *Callistemon*, *Melaleuca* and other genera, have been drawn up when the buds and fruits were only half developed. When it is realized that the fruits in which the seeds are contained vary from seven months after the flowering period in certain species to two and a half years in other species of the same genus, before they are fully developed so as to yield viable seeds, it will at once be seen how discrepancies have crept in, and difficulties thus created in working out the species from faulty descriptions.

During the past decade much has been written and published concerning the genetic relation of plants. Only by culture combined with cytological studies will it become possible to determine the genetic relation of the numerous microspecies. Darwin's theory of the origin of species presupposes the occurrence of occasional varieties from the parent stock, of which some are preserved and fostered by natural selection. The cause of this variation has been sought in various quarters, and, indeed, it is to be presumed that it is due not to one cause but to many. It has been suggested that hybridization is one of the chief causes of variation. There must be abundant opportunities for natural crossing. In view of this, we may expect to find in nature what are termed polymorphic species, with their segregates, complicated with re-hybridization, and thus we have what have recently been termed "highly polymorphic swarms of hybrids".

When we consider the general prevalence of *Eucalyptus*, the frequent association of numerous species and forms or varieties in the same locality, the large number of flowers produced by an individual tree, each of these flowers on the same tree showing variable characters, and, most important of all, the millions of individual pollen-grains which are the units or sires of future generations, we may expect that certain characters will be transmitted to their offspring. It is for this reason that species, as well as varieties, have been regarded as abstractions, in other words, that which is taken or derived from something else. Nature consists of individuals; similar (not identical) individuals are raised from syngameums (the cell which arises from the fusion of two gametes) and these, I am afraid, have been frequently mistaken for species. Formerly these were all included in the Linnaean system of grouping, which has served a very useful purpose in the classification of plants. We must be very careful in adopting new systems which tend to split the Linnaean species into innumerable forms of microspecies.

Dr. A. B. Droogleever Fortuyn in a paper entitled "A Recent Modification of the Species-Idea" ("Nature", 1927, p. 933) states:

"We cannot define a species as a group of organisms having the same genotype, for it is known that often the male and female of one species differ in the number of their chromosomes and in the number of their genes. . . The Hagedoorns urge us to remember that a species is a natural phenomenon and not a theoretical species. Species as found in nature are mixtures of genotypes, so if we follow Johannsen and term such a mixture of genotype as a population, for a species is a population, but not every population is a species. In order to be a species the individuals of a group must interbreed. Therefore a species is a mixture of genotypes freely interbreeding and containing some types of homozygotes as well as several types of heterozygotes or hybrids."

E. S. Goodrich ("Living Organisms", Clarendon Press, 1924, p. 15) called a species "An assemblage of closely allied interbreeding races differing from one another by small factorial differences and representing as a whole its present phase of evolution."

The great plasticity of such a definition is obvious. Although a species is inconstant and genetically impure (that is, composed of many genotypes and their hybrids) it always tends to become more constant and more pure because in the struggle for existence an elimination of ill-adapted genotypes takes place and because new genotypes may only be introduced through rare cases of mutation

or of crossing with other species. Variation is found everywhere, for the reason that a species is a population of many genotypes.

It is suggested that the more obvious botanical changes have been mainly due to slow evolutionary development under the influence of environment, soil and climate. Altitude, climate and soil seem to be the chief controlling factors governing the geographical range of most species. The adaptation of the various species is traceable, largely, to influences of chemical constituents, which, under natural conditions, where the struggle for existence is exerted to the fullest, govern the establishment of a species in its earliest stages. It does not seem possible for a certain species to grow satisfactorily in soil not congenial to its requirements. This may account for the extreme variation which we see in the material in various herbaria of *Leptospermum scoparium*, which has been gathered together from a wide range of localities very different climatically and geologically. Some of these assume forms as discrepant as those of the "Stringybark" forms of *Eucalyptus* and several other highly variable and extensively distributed species of the same genus. Nature is infinitely complex and is everywhere instinctive with life: attractive and repulsive chemical forces are exerted over atoms and bodies and equally over the physical or physiological conditions of plant life. Therefore, we have only to push our experiences far enough to find that our physical laws are imperfectly stated and our physical models inadequate.

Ecological Factors in Relation to the Distribution of Myrtaceae.

Until comparatively recent times, what is now conceived as ecology was included under biology. Biology is a general term including botany and zoology, and ecology is a part of each. Ecology as a science is a branch of botany which is concerned with the relations of the individual plant, the species and the community to the site. As already stated by Cockayne (1917, p. 162) "Botanical ecologists endeavour to define and classify the physiological requirements of the species which, although they fit fairly well into one or other of the recognised aggregate species, differ so greatly in their ecological requirements from other members of the species to which they are referred, that to call them by the same name is most misleading, and in no few instances will cause incorrect ecological deductions."

We know that climatic conditions affect certain plant species very considerably —so much so that we find a given species with apparently well defined characters at certain altitudes, but when the species is grown under different climatic conditions, those characters are considerably changed. Trees, of course, are the dominant members of a plant community of which they form a part, so that we may regard the distribution of trees as of very great ecological and economic importance in that they control the distribution of other species.

What may be regarded as a very logical statement in regard to the cause of change of flora under the same climatic conditions is that made by the late Mr. R. H. Cambage, as follows: "As climatic conditions, rainfall and aspect are similar over a great part of the Western Plains, the various changes in the flora may be regarded as due to the variations in the geological formations, or to the difference between rocky and alluvial situations; and some of these changes are very marked." It has also been pointed out by Cambage that "Generally speaking, the flora of the red and black soil plains are distinct, and in several instances

certain genera may be represented by species which are peculiar to the one or other class of soil."

The deductions we may draw from this latter statement are that every species of plant depends for its existence upon a certain class of soil, that is to say, the plant may, from its peculiar individual organization, demand peculiar soil formation. If the conditions of existence are special, the plant cannot be widely diffused, if general, the diffusion will be proportionately extensive. Hence we find, for example, that the conditions are special in the case of *Melaleuca coriacea* and other closely related forms or subspecies, as well as in *Leptospermum scoparium* and several of its forms or subspecies, which are distributed over a wide range of climatically and geologically very different localities.

The term "plant association" does not imply a harmonious concurrence of diverse activities working towards a common end, as in every society founded on division of labour. It is applied to the coexistence of forms which, specifically and morphologically, are foreign to one another, each having as its object its own exclusive profit. They live side by side according to the similarity or the diversity of their requirements, which find their satisfaction either in the same conditions of environment or in conditions determined by the presence of the other organisms. Plant association is the final expression of the struggle for existence and of adaptation to the environment in the grouping of species. The inhabitants of the same station are connected not only by the bonds of co-existence, but also by a bond of reciprocal interest, some at least finding advantage and profit in the conditions determined by the presence of others. When the leaves of a tree or any kind of plant fall to the ground, they begin to decay and ultimately they are disintegrated and their substance becomes incorporated with other elements of the soil. The same thing happens with the stems and roots of herbaceous plants, as well as the smaller twigs or branches of shrubs and trees. Such organic matter, which is usually termed "leaf-mould" or humus, is one of the chief sources of food for plants, and its presence in the soil is therefore of fundamental importance in the maintenance of all kinds of vegetable growth of the earth. When the vegetable matter is in the process of decomposition it is said to produce, under certain circumstances, a condition of soil acidity, and under other circumstances a condition of alkalinity.

It will be seen from this that the acidity or alkalinity of the soil must have an important bearing on plant ecology, and that a knowledge of this phenomenon is essential to a correct understanding of the distribution of plants. We often wonder why a plant taken from its natural surroundings will not thrive under cultivation. The "Blueberry Plant" (*Vaccinium* spp.) for instance, and certain other associated species, require a condition of acidity and will only grow successfully in certain acid soils, composed chiefly of partially rotted Oak leaves. When Oak leaves had been rotting for a period of about five years, and had become a black, mellow, vegetable mould, however, the "Blueberry Plants" did not grow so luxuriantly, but, on the contrary, their leaves turned purple and afterwards yellowish, and then dwindled away. The same set of circumstances seems to me to apply to many species of our Australian flora. If we were to study the distribution of larger natural units (groups of species and genera) rather than individual species, we might perhaps arrive at a better solution of the problem of plant distribution.

Plant association would appear to be the final expression of the struggle for existence and adaptation to the environment in the grouping of species. Adaptation may imply, broadly, any means by which a plant is enabled to survive in its surroundings, not as an individual, but as a species. The term so understood means not merely the ability to survive, but the ability to survive without alteration of certain characters. To all these considerations must be added the early migrations which the different families or tribes of plants passed through under the changing conditions imposed upon them by geographical and climatic necessities, and thus a systematic arrangement of facts is finally indicated.

Plants of closely allied species often grow in quite different communities and this has been found to apply often to varieties of the same species. As examples we may cite the various species of *Melaleuca* and *Leptospermum* previously alluded to, as well as *Eucalyptus haemastoma*, which is found in sandstone country along the coastal belts of New South Wales and Queensland, usually associated with such plants as *Dillwynia ericifolia* and *Tetratheca ericifolia*, while, on the other hand, *Eucalyptus micrantha*, which by many botanists is regarded as a variety of *E. haemastoma* (having practically the same general appearance in the colour of the bark, markings, etc., for which reason both forms or subspecies are commonly known as "Scribbly Gum"), is chiefly found on sandstone slopes of the Tableland from Hill Top to Mittagong and on the Blue Mountains, associated with *Dillwynia glabra* and *D. spinescens*, *Tetratheca thymifolia*, all of which have been at one time or another regarded as belonging to one species, viz., *Eucalyptus micrantha–E. haemastoma*; *Dillwynia glabra* and *D. spinescens–D. ericifolia*; and *Tetratheca thymifolia–T. ericifolia*.

Essential Oils from Australian Leptospermoideae (Myrtles).

Attention has frequently been drawn to the pioneer work in connection with certain essential oils obtained from Myrtaceous plants in Australia by John White, Surgeon-General to the First Fleet, which arrived in Port Jackson in 1788, and also Surgeon D. Considen. Whilst a definite species of Eucalyptus, viz., *E. piperita*, is mentioned by White (1790), Considen (1892) refers to five or six species of wild Myrtles, without giving specific details. We can readily assume, however, that the Myrtles referred to belong to the Leptospermoideae group of Myrtaceae, which are so common in the Port Jackson district. As a medicinal remedy, the "Oleum Eucalypti" of the British Pharmacopoeia, which is the oil distilled from the fresh leaves of several species of *Eucalyptus*, has gained world-wide fame. In view of this, there seems to be no valid reason why hundreds of thousands of pounds should have been sent away annually to Europe to bring us medicines, drugs and other useful chemical substances, when they could have been produced here. Through the researches of Messrs. R. T. Baker and H. G. Smith, who have made history in their elaborate work on Australian plants yielding essential oils, as well as those researches in a similar connection conducted more recently by Messrs. A. R. Penfold and F. R. Morrison at the Technological Museum, new essential oils, new sources of dyes and other chemical substances have been brought vividly under our notice through their various publications.

Botanists are, on the whole, perhaps more usually concerned with the morphological aspects of plant life than with the chemical substances or other products yielded by plants, which may or may not be of some commercial or economic importance. During comparatively recent years scientists have turned their

attention to the natural chemical resources of Australia and commercial possibilities of various species of Australian plant-life, and as a result of extensive botanical research, combined with chemical investigations, great numbers of species of the Myrtaceae have been exploited for their potential wealth. There is no unworked field of original research so attractive and which promises to be so productive as does the question of odorous leaves. The presence of a fragrant aromatic or pungent volatile oil is indicated by the pellucid dots of the leaves of practically the whole of the species of the Myrtle family. These transparent glands, which in reality are tiny cells containing essential oils, are easily seen by the naked eye if held up to the sunlight, more especially by the aid of an ordinary pocket lens.

Careful observation of the botanical features of many of the Australian Myrtles, especially those species classed in the subfamily Leptospermoideae, has revealed to us that when the whole of the species have been tested for the various products likely to be of some use to man and beast, the Myrtle products will form a most valuable asset to the Empire.

The problem of conducting further experiments and chemical researches is essentially a national undertaking and can only be exploited by the aid and co-operation of the botanical and forestry departments of the various States and co-ordinated by the Federal authorities.

When we compare the numerous chemical substances obtained during the past decade or two from our Australian Myrtles with those from other countries, it will be found that Australia has been very fortunate in having so many distinguished workers in the domain of chemistry and therapeutics of our native plants. We have only to examine the pioneer work of those earlier explorers to find out what yeoman service has been rendered to the whole human race. The statement of Captain William Dampier, who anchored in Shark's Bay on the 5th January, 1688, is of special interest, as it will be seen that he was the first to land on the shores of Australia, and also the first to note that certain trees yielded "gum out of the knots or cracks". The following is a copy of his statement (1699):

"The land was of a dry sandy soil, destitute of water, except you make wells: yet producing divers sorts of trees: but the woods are not thick, nor the trees very big. Most of the trees that we saw are Dragon-trees as we supposed, and these too are the largest trees of any there. They are about the bigness of our large Apple trees and about the same height, and the rind is blackish and somewhat rough. The leaves are of a dark colour. The gum distils out of the knots or cracks that are in the bodies of the trees. We compared it with some Gum Dragon or Dragon's Blood that was aboard, and it was of the same colour and taste. The other sorts of trees were not known by any of us. There was pretty long grass growing under the trees, but it was very thin. We saw no trees that bore fruits or berries."

In a further statement Dampier states (Vol. iii, p. 84, 3rd Ed.): "Farther in, the mould is reddish, a sort of sand producing some grass plants and shrubs. Of trees and shrubs here are divers sorts, but none above 10 foot high, their bodies about 3 foot about, and 5 or 6 foot high, before you come to the branches, which are bushy and composed of small twigs there spreading abroad, tho' thick set and full of leaves, which were mostly long and narrow. The colour of the leaves was on one side whitish and on the other green, and the bark of the trees was generally of the same colour with the leaves of a pale green. Some of these trees

were sweet-scented and reddish within the bark, like Sassafras, but redder. Most of the trees and shrubs had at this time either blossoms or berries on them. The blossoms of the different sort of trees were of several colours, as red, white, yellow, etc., but mostly blue. And these generally smelt very sweet and fragrant, as did some also of the rest. There were also besides some plants, herbs and tall flowers, some very small flowers growing on the ground that were sweet and beautiful, and for the most part unlike any I had seen elsewhere."

It will be seen from the above that the economic resources of the Australian vegetation were under review by the great buccaneer and navigator Dampier as far back as 1688, and was followed up by John White, Surgeon-General to the First Fleet which arrived in Port Jackson in 1788.

During Captain Cook's second voyage to these regions a plant commonly known as "Tea Tree" (*Leptospermum scoparium*) found on the coast of New Zealand, where it was discovered by Sir Joseph Banks and Dr. Solander, was thought by Captain Cook to have been serviceable to the health of the crew. "Its infusion or tea is pleasantly aromatic and fragrant, if not suffered to stand too long, in which case it becomes bitter. Mixed with an equal quantity of the New Zealand Spruce (*Dacrydium*) it was found to make excellent and highly palatable beer of the most salutary quality, the *Dacrydium* being too astringent alone."

The essential oil obtained from the leaves of various species of the Leptospermoideae group of Australian Myrtaceae is extremely variable, both in yield and quality, and although some of them may not be of any economic value, the results of the investigations are certainly of scientific interest. Some of the trees yielding these oils, such as *Eucalyptus*, *Melaleuca* and *Syncarpia*, are large and the collection of the foliage would involve a considerable amount of labour, while of others, such as *Leptospermum*, *Darwinia*, *Homoranthus*, *Backhousia*, *Kunzea*, *Baeckea*, *Calycothrix* and the "Mallee" forms of *Eucalyptus*, the foliage is easy to collect.

The prospective value of some of these oils seems to indicate that there is a bright future before us if we can overcome the labour difficulties. It is claimed, for example, that the essential oil from *Melaleuca alternifolia* is superior in many respects to those previously on the market, such as carbolic acid, and used as a germicidal disinfectant. In other words, it has been found that the oil from *Melaleuca* is from eleven to thirteen times more powerful or effective in destroying typhoid germs than carbolic acid under similar conditions. It is also stated to be extremely valuable in dentistry. During recent years a marked impetus has been given to the disinfectant industry, owing to the discovery that in the rectification of crude Eucalyptus oils for pharmaceutical use, about 10 to 15 per cent. left behind in the distilling vessel possesses very pronounced germicidal and insecticidal properties. These uses apply more especially to the phellandrene oils, which during the war period were also used extensively for industrial purposes in the separation of certain useful minerals in the flotation process. Quite recently Mr. A. R. Penfold has also drawn attention to the use of this type of oil in the boot-polish trade and as a useful solvent for paints and varnishes. It is also interesting to note that some of the preparations made from these oils are already ousting some of the old-established coal-tar preparations from the Australian trade. Besides the above, there are many other uses to which the Eucalypts can be applied with more or less beneficial results—the latest being Eucalypt-leaf cigarettes known as "Eucarettes".

The use of essential or volatile oil for commercial purposes, especially in the manufacture of perfumes and scented soaps and as primary materials in various kinds of synthetic products, is increasing each year, as will be seen from the reports in connection with the lemon-scented oils from Grasses (*Chrysopogon* and *Vetiveria*) which form an important industry in Ceylon and Singapore, amounting to thousands of pounds annually in their trade with Great Britain. There seems to be no valid reason why Australia should not be able to capture some of this trade, as it has been clearly demonstrated that our Australian plants such as the "Lemon-scented Ironbark" (***Eucalyptus Staigeriana***), "Lemon-scented Gum" (***Eucalyptus citriodora***) and the "Lemon-scented Tea Trees" (***Leptospermum citratum*** and *L. Liversidgei* (*L. flavescens* var. *citriodora* of Bailey), as well as *Backhousia citriodora*) are superior in certain respects, particularly in regard to yield, and should be able to hold their own in their natural soil if they were extensively cultivated. Many other species of the Australian Myrtaceae have been shown to possess valuable products, such as Geranyl-acetate, Piperitone, Thymol, Cajuput and such-like chemical substances, which are valued in the older countries to such an extent that vast quantities of seeds have been obtained with a view to extensive cultivation in Asia, Africa and America for the products alone.

Colloquial or Vernacular Names.

The subject of giving plants a vernacular or colloquial name is one that has frequently been discussed in recent years. The popular idea is to adopt short names in the vernacular and give up the scientific names altogether. This may seem feasible to some persons who have not considered the subject in its wider aspects, for they forget that the popular names of plants of one district are not those of another.

We have only to scrutinize the list of 1500 colloquial names that have already been applied to various species of *Eucalyptus* and published in works dealing with this genus, to be able to realize the difficulties that are involved in trying to cope with the bushman's idea of naming plants.

The term "Gum Tree" is usually applied to those species of *Eucalyptus* that shed their bark and ultimately have a clean, smooth-barked bole or trunk. The names "Blue", "White", "Grey" and "Spotted" are applied indifferently to several species. The best known member of the "Blue Gums" is *Eucalyptus globulus*, but it is most difficult to separate the New South Wales form of "Blue Gum", recently described as a new species under the name *Eucalyptus bicostata*, from the "Tasmanian Blue Gum" (*Eucalyptus globulus*). In fact, several forms, such as *E. St. Johnii*, *E. Mortoniana*, *E. Cordieri*, *E. antipolitensis*, *E. Bourlieri* and *E. pseudo-globulus* have very similar juvenile leaves, and the young stems of the seedlings and reversionary shoots are glaucous or blue-green and quadrangular. Without flowers or fruits it is very difficult to distinguish one from the other, and for many years *E. bicostata* was regarded as being identical with *E. globulus* and cultivated extensively under the latter name. The buds and fruits of certain forms of the above-mentioned species vary considerably from the original "Tasmanian Blue Gum" (*E. globulus*) and it is by these characters that the authors of the species have been prompted to give distinctive specific names. Whether the offspring of these will breed true remains to be seen. We do know, however, that a great number of people who are interested in these trees have very little knowledge concerning the structure of the floral or carpological charac-

ters, and even if they had, it not infrequently happens that several years elapse before seedlings reach the flowering stage.

It is therefore extremely difficult for those interested in our plants, either from a floricultural or arboricultural point of view, or on account of the economic importance of the essential oils or other products, to keep a correct standardized catalogue of nomenclature.

The term "Mallee" is applied to certain species of Eucalypts which form the Mallee Scrub typical of hundreds of square miles of country in the western parts of New South Wales and in the Mildura and Swan Hill districts of Victoria, extending through South Australia and Nullarbor Plains to Western Australia and Yorke Peninsula. The most important species are *Eucalyptus dumosa*, *E. oleosa*, *E. gracilis* and *E. fruticetorum* (*E. polybractea*). Since the above were described, many years ago, upwards of one hundred additional species have been described, which are more local in their habitat and are known as Mallees. To be able to become familiar with this formidable list of Mallees is quite a task, so that an effort has been made to classify the various species as nearly as possible into their strict botanical sequence and allot each a definite numeral. By this numerical system non-botanists, who do not understand botanical technique, can at once have access to the different forms of Mallees or Gums or Boxes or Ironbarks, as each of the species has a definite number, and colloquial or vernacular names applied to the respective species have a numeral corresponding with the species.

Conclusion.

In conclusion may I say that in an address of this kind one can only give a cursory glance at the vegetation as a whole, and even this imperfect collection of data is taken from a very limited number of species, chiefly from one family, with a view of trying to awaken new sources of enquiry among thoughtful people, which may ultimately lead to further investigations being made in other channels. A large mass of additional evidence bearing upon the subject requires more labour than I have found time to bestow, and would also unreasonably swell this already lengthy address.

The objective of this Society is the advancement of natural history by original investigation. As a result of such investigation much scientific knowledge has been acquired and recorded in the PROCEEDINGS of this Society during the past fifty-five years. It is our duty to educate the public by all possible means to a realization of the value of many of our native trees and shrubs, and the evils resulting from their destruction. It is a matter of national importance, and is a subject for capable statesmen to handle, who should make the knowledge of our research workers available. Research workers are imbued with the spirit of enquiry, and, as a rule, are quite indifferent to applied science. Science is one thing, the application of it is another.

In view of this, it is all the more important that we should ponder over the teachings of such eminent scientists as Professor Huxley, who once remarked that "Educated publicity agents were a valuable asset to any community because they made knowledge available". If we were able to obtain the services of the right kind of publicity agents we should then be able to bring together minds occupied with similar tasks, thus create a clearing house of scientific knowledge, and so save a certain amount of waste expenditure of thought and research, which comes of a too rigidly independent habit of investigation. We require not merely the

development of a theory, but a system of principles and the results attained in practice.

At the present time it takes us half our lives to unlearn and eradicate errors honestly taught us in youth with perfect good faith and intention, which persistently cling to us until displaced by the sound reasoning powers of maturer years. To overcome this we require a periodical system of "stock-taking in science", so as to be able to keep in touch with what has already been achieved, and thus follow on the lines of Macaulay who remarked "That which was in the distance yesterday is its goal to-day and will be its starting place to-morrow".

I am indebted to Mr. A. R. Penfold, F.A.C.I., F.C.S., Curator and Economic Chemist, Technological Museum, Sydney, who has very kindly prepared samples of the following essential oil constituents which I exhibit for your examination:

Citral.—Principal constituent of *Backhousia citriodora* and occurs to extent of 50% in *Leptospermum citratum*. Present in some Eucalyptus oils.

Citronellal.—Principal constituent of *Eucalyptus citriodora* and occurs to extent of about 40% in *Leptospermum citratum*.

Geraniol.—Combined with acetic acid is present as ester in *Eucalyptus Macarthuri* and *Darwinia fascicularis*.

Geranyl-Acetate.—See under Geraniol.

Darwinol.—Combined with acetic acid as ester is present in *Darwinia grandiflora* and *Leptospermum lanigerum*.

Pinene.—The principal terpene of most essential oils of the Myrtaceae; l-α-pinene abundant in *E. phlebophylla*.

Phellandrene.—The principal terpene of many Eucalyptus oils, such as *E. dives*, *E. numerosa*, etc.

Methyl-Eugenol.—Principal constituent oil of *Melaleuca bracteata*.

Piperitone.—The peppermint constituent of *Eucalyptus dives*, etc. Occurs to the extent of 50%.

Limonene.—Principal constituent of *Eucalyptus Staigeriana*.

Angustione.—Principal constituent of *Backhousia angustifolia* (occurs to the extent of 75%). Chemically is a β-diketone.

Elemicin.—Principal constituent of *Backhousia myrtifolia*.

Terpinenol-4.—The alcoholic constituent of *Melaleuca alternifolia* and *M. linariifolia*.

Ocimene.—Principal constituent of *Homoranthus flavescens*.

Australol.—The principal phenolic constituent of the "Mallee" Eucalyptus oils.

Cryptal.—An aldehyde occurring in the "Mallee" Eucalyptus oils.

Piperitol.—The alcohol corresponding to Piperitone. Present in greatest quantity in *Eucalyptus numerosa*.

Eudesmol.—The white solid sesquiterpene alcohol present in many Eucalyptus oils and in *Leptospermum odoratum*, *L. flavescens*, etc.

Cineol.—The principal constituent of medicinal Eucalyptus oils. Present also in many Myrtaceae.

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Dr. G. A. Waterhouse, Honorary Treasurer, presented the balance sheets for the year 1930, duly signed by the Auditor, Mr. F. H. Rayment, F.C.P.A., Chartered Accountant (Aust.); and he moved that they be received and adopted, which was carried unanimously.

No nominations of other Candidates having been received, the Chairman declared the following elections for the ensuing Session to be duly made:—

President: Professor T. G. B. Osborn, D.Sc.

Members of Council: W. R. Browne, D.Sc., Sir T. W. E. David, K.B.E., C.M.G., M.A., D.Sc., F.R.S., W. W. Froggatt, F.L.S., A. H. S. Lucas, M.A., B.Sc., G. A. Waterhouse, D.Sc., B.E., F.E.S., W. L. Waterhouse, D.Sc.Agr.

Auditor: F. H. Rayment, F.C.P.A.

A cordial vote of thanks to the retiring President was carried by acclamation.

Linnean Society of New South Wales

GENERAL ACCOUNT. Balance Sheet at 31st December, 1930.

LIABILITIES.	£	s.	d.	£	s.	d.
Capital: Amount received from Sir William Macleay during his lifetime	14,000	0	0			
Further sum bequeathed by his Will	6,000	0	0			
				20,000	0	0
Contingencies Reserve				11,820	0	0
Fletcher Memorial Fund at 31st December, 1930				23	17	0
Income A/c at 31st December, 1930				18	7	3
Commercial Banking Coy. of Sydney, Ltd.				631	6	9
				£32,493	11	0

ASSETS.	£	s.	d.	£	s.	d.
Society's Freehold				11,000	0	0
Investments: Commonwealth Loans	3,063	11	0			
Loans on Mortgage	6,600	0	0			
Science House	11,820	0	0			
				21,483	11	0
Cash in hand				10	0	0
				£32,493	11	0

INCOME ACCOUNT. Year Ended 31st December, 1930.

	£	s.	d.	£	s.	d.
To Salaries and Wages				1,175	0	0
„ Printing Publications	826	5	2			
„ Illustrations	142	15	6			
				969	0	8
„ Rates and Insurance				262	18	0
„ Postage	53	0	4			
„ Petty Cash	29	5	3			
				82	5	7
„ Audit	7	7	0			
„ Printing and Stationery	21	14	10			
„ Expenses	36	17	5			
„ Attendance	8	10	0			
„ Legal Expenses	25	0	0			
„ Lamarck Memorial	10	10	0			
„ Fletcher Memorial Lecture	21	0	0			
„ Bank Expenses	3	8	10			
„ Repairs	16	7	6			
				150	15	7
„ Library and Bookbinding				126	11	6
„ Appropriation: Contingencies Reserve				820	0	0
„ Balance to 1931				18	7	3
				£3,604	18	7

	£	s.	d.	£	s.	d.
By Balance from 1929				9	5	3
„ Subscriptions: 1930	149	2	0			
Arrears	17	17	0			
In Advance	6	6	0			
				173	5	0
„ Life Subscriptions				15	15	0
„ Entrance Fees				17	17	0
„ Interest				1,012	8	1
„ Rents				769	1	8
„ Sales (including 100 copies of Proceedings purchased by Government of New South Wales)				200	6	3
„ Fellowships A/c (surplus income transferred)				1,407	0	4
				£3,604	18	7

Examined and found correct. Securities produced.
F. H. RAYMENT, Chartered Accountant (Aust.),
Auditor.
Sydney, 9th February, 1931.

G. A. WATERHOUSE,
Hon. Treasurer.
19th January, 1931.

Linnean Society of N.S.W.—Wildflower Series, No. 2.—*Telopea speciosissima.* The Waratah.
(About half normal size.)
(Reproduced by kind permission of the Government Printer, Sydney.)

LINNEAN MACLEAY FELLOWSHIPS ACCOUNT.

BALANCE SHEET at 31st December, 1930.

LIABILITIES.	£	s.	d.	ASSETS.	£	s.	d.
Amount bequeathed by Sir William Macleay	35,000	0	0	Commonwealth Loans	9,105	12	0
Surplus Income capitalized	13,218	6	8	N.S.W. Debentures	530	0	0
				Loans on Mortgage	37,700	0	0
				Commercial Banking Coy. of Sydney, Ltd.	882	14	8
	£48,218	6	8		£48,218	6	8

INCOME ACCOUNT. Year Ended 31st December, 1930.

	£	s.	d.		£	s.	d.
To Salaries of Linnean Macleay Fellows	733	6	8	By Interest	3,063	8	1
„ Fellows' Subsidies	56	7	9				
„ Capital A/c	866	13	4				
„ General A/c	1,407	0	4				
	£3,063	8	1		£3,063	8	1

Examined and found correct. Securities produced.
F. H. Rayment, Chartered Accountant (Aust.),
Auditor.
Sydney, 9th February, 1931.

G. A. Waterhouse,
Hon. Treasurer.
19th January, 1931.

BACTERIOLOGY ACCOUNT.

BALANCE SHEET at 31st December, 1930.

LIABILITIES.	£	s.	d.	ASSETS.	£	s.	d.	£	s.	d.
Amount bequeathed by Sir William Macleay	12,000	0	0	Commonwealth Loans				15,330	0	0
Accumulated Income capitalized	3,800	0	0	N.S.W. Debentures				470	0	0
Income A/c at 31st December, 1930	534	3	2	Cash: Commercial Banking Company ..	132	16	7			
				Government Savings Bank	395	6	7			
				In hand	6	0	0			
								534	3	2
	£16,334	3	2					£16,334	3	2

INCOME ACCOUNT. Year Ended 31st December, 1930.

	£	s.	d.	£	s.	d.		£	s.	d.
To Salary				600	0	0	By Balance from 1929	543	1	1
„ Apparatus and Chemicals				138	18	7	„ Interest	816	5	6
„ Storage and Cartage	62	15	0							
„ Periodicals	2	0	0							
„ Expenses	18	3	8							
				82	18	8				
„ Petty Cash				3	6	2				
„ Balance to 1931				534	3	2				
				£1,359	6	7		£1,359	6	7

Examined and found correct. Securities produced.
F. H. Rayment, Chartered Accountant (Aust.),
Auditor.
Sydney, 9th February, 1931.

G. A. Waterhouse,
Hon. Treasurer.

19th January, 1931.

ABSTRACT OF PROCEEDINGS.

ORDINARY MONTHLY MEETING.

25th MARCH, 1931.

Professor T. G. B. Osborn, D.Sc., President, in the Chair.

The Donations and Exchanges received since the previous Monthly Meeting (26th November, 1930) amounting to 20 Volumes, 217 Parts or Numbers, 13 Bulletins, 11 Reports and 76 Pamphlets, received from 112 Societies and Institutions and 1 private donor, were laid upon the table.

PAPERS READ.

1. Petrology of the Hartley District. i. The Plutonic and Associated Rocks. By Germaine A. Joplin, B.Sc.

2. The Gasteromycetes of Australasia. x. The Phallales. Part i. By G. H. Cunningham, Ph.D.

3. Notes on Australian Diptera. xxvii. By J. R. Malloch. (*Communicated by Dr. G. A. Waterhouse.*)

ORDINARY MONTHLY MEETING.

29th APRIL, 1931.

Mr. E. Cheel, Vice-President, in the Chair.

The Chairman announced that the Council had elected Mr. H. J. Carter, Dr. W. R. Browne, Dr. H. S. H. Wardlaw and Mr. E. Cheel to be Vice-Presidents, and Dr. G. A. Waterhouse to be Honorary Treasurer for the current Session.

The Chairman also announced that the Council had elected Mr. T. C. Roughley to fill the vacancy on the Council caused by the resignation of Mr. G. M. Goldfinch.

The Chairman reminded members that the official opening ceremony of Science House will take place on Thursday, 7th May, at 3.30 p.m., when the building will be declared open by His Excellency the Governor.

The Chairman informed members that the Council had again given its support to a movement by the Killara Community Service Club to have the proclamation protecting certain wild flowers extended for another year.

The Chairman drew the attention of members to the fact that the coloured illustration of the Waratah, which was issued as a plate with Part 1 of the PROCEEDINGS, is available for sale printed on postcards.

The Donations and Exchanges received since the previous Monthly Meeting (25th March, 1931) amounting to 27 Volumes, 200 Parts or Numbers, 10 Bulletins, 3 Reports and 13 Pamphlets, received from 87 Societies and Institutions and 3 private donors, were laid upon the table.

PAPERS READ.

1. The Physiography of the Shoalhaven River Valley. i. Tallong-Bungonia. By Frank A. Craft, B.Sc., Linnean Macleay Fellow of the Society in Geography.

2. Further Notes on the Orchids of the South Maitland Coalfields, with Description of a New *Dendrobium* from Bullahdelah. By Rev. H. M. R. Rupp, B.A.

3. Contributions to our Knowledge of the Actinomycetales. i. A Case of Hereditary Variation in the Genus *Actinomyces*. By H. L. Jensen, Macleay Bacteriologist to the Society.

NOTES AND EXHIBITS.

Mr. David G. Stead referred to an extraordinary example of the effect of wind and current following the recent wreck of the M.S. *Malabar* at Long Bay, a little to the south of Sydney Heads. Within a period of 36 to 40 hours following the bursting open of the ship's sides a butcher's block (wood) brought up on the coast at Newcastle—a drift of about 60 miles. The main current on this coast is a broad, deep south-flowing one, but close inshore are a series of back-flowing eddies which work to the north. Small vessels take advantage of this northerly "set" when moving in a northerly direction along the coast. Immediately following the wreck of the *Malabar* there was a continued southerly breeze.

Dr. G. A. Waterhouse exhibited specimens of both sexes of *Papilio dardanus cenea* from Natal, South Africa, and drew attention to the great differences in the females, which are so unlike the males.

Mr. W. W. Froggatt exhibited (1) normal male and female galls of *Apiomorpha maliformis* Fuller on twigs and foliage of Blackbutt, *Eucalyptus patens*, from Western Australia; (2) abnormal female galls growing out of the stem on the same Eucalyptus from Western Australia; and (3) the great coconut-palm longicorn, *Xixuthus costatus* Montrz., from the Solomon Islands. This beetle is figured and noted in "Pests and Diseases of the Coconut Palm", by W. W. Froggatt (Third Edition, 1914).

ORDINARY MONTHLY MEETING.

27th May, 1931.

Mr. E. Cheel, Vice-President, in the Chair.

Mr. Harold W. Hamilton, Burwood, was elected an Ordinary Member of the Society.

The Chairman announced that Professor W. E. Agar, of the University of Melbourne, had accepted the Council's invitation to deliver the Fletcher Memorial Lecture for 1931. The lecture will be delivered on Monday, 9th November.

The Chairman called the attention of members to the proposal by the Hawkesbury Agricultural College Old Boys' Union for the institution of a memorial to the late Mr. H. W. Potts.

The Chairman brought to the attention of members the booklet, "Tree Planting on the Farm", published by the Department of Agriculture, which is available from the Department at a small charge.

The Donations and Exchanges received since the previous Monthly Meeting (29th April, 1931) amounting to 6 Volumes, 120 Parts or Numbers, 10 Bulletins, 6 Reports and 6 Pamphlets, received from 76 Societies and Institutions and 1 private donor, were laid upon the table.

PAPERS READ.

1. On Baridiinae (Curculionidae), mostly from New Guinea. By A. M. Lea, F.E.S.

2. The Gasteromycetes of Australasia. xi. The Phallales. Part ii. By G. H. Cunningham, M.Sc., Ph.D.

3. The Life-history of *Calliphora ochracea* Schiner (Diptera, Calliphoridae). By Mary E. Fuller, B.Sc.

4. A Note on the Systematic Position of *Mycobacterium coeliacum* Gray and Thornton. By H. L. Jensen, Macleay Bacteriologist to the Society.

NOTES AND EXHIBITS.

Mr. David G. Stead sent for exhibition two immature examples of the Dart, *Trachinotus botla* (Shaw). This edible fish is commonly a northern species and is not often taken so far south as Port Jackson. The two specimens shown are of particular interest because of their small size (193 mm. and 178 mm. respectively). They were portion of a large shoal of similar size in the lower part of Port Jackson on 21st May. During the winter of 1907 several hundreds from 300 mm. to 375 mm. in length were taken in Botany Bay. In tropical waters this species is very abundant; also in Malayan waters, where it is known by the Malay name of *Ikan Nyior-Nyior*.

Dr. W. L. Waterhouse exhibited plants resulting from crossing "Bunyip" wheat and "Rosen" rye. These have proved sterile in all cases. Even back-crossing with each of the parents has not given grain. The F1 plants resulting from crossing the vulgare wheat "Gullen" with the emmer known as "Khapli" were also shown. By pollinating the flowers with pollen of "Gullen" it has been possible to obtain a number of grains, many being plump and apparently normal. Similar results on a somewhat smaller scale were reported when the varieties "Bunyip", "Canberra", "Exquisite" and "Geeralying" were used as the vulgare parents in place of "Gullen".

ORDINARY MONTHLY MEETING.

24th June, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

The Chairman referred, with regret, to the death of Dr. A. Eland Shaw, who had been a member of the Society since 1922.

The Chairman, on behalf of members, offered congratulations to Professor T. T. Flynn on his appointment to the Chair of Zoology of the Queen's University, Belfast.

The Chairman drew the attention of members to a tree planting ceremony on Saturday, 25th July, at 2 p.m., inaugurating a scheme for beautifying Ball's Head Reserve.

The Chairman announced to members that it is proposed to hold a Special General Meeting immediately before the next Monthly Meeting on 29th July to put forward a proposal for the admission of Associates to the Society.

The Donations and Exchanges received since the previous Monthly Meeting (27th May, 1931) amounting to 14 Volumes, 123 Parts or Numbers, 5 Bulletins, 5 reports and 15 Pamphlets, received from 74 Societies and Institutions, were laid upon the table.

PAPERS READ.

1. Trichopterygidae of Australia and Adjacent Islands. By C. Deane.

2. Notes on the Biology and Morphology of the Eurymelinae (Cicadelloidea, Homoptera). By J. W. Evans, M.A., F.L.S. (*Communicated by Dr. R. J. Tillyard.*)

3. The Physiography of the Shoalhaven River Valley. ii. Nerrimunga Creek. By F. A. Craft, B.Sc., Linnean Macleay Fellow of the Society in Geography.

4. The Physiography of the Shoalhaven River Valley. iii. Bulee Ridge. By F. A. Craft, B.Sc., Linnean Macleay Fellow of the Society in Geography.

5. Three new bats, of the genera *Pteropus*, *Nyctimene*, and *Chaerephon*, from Melanesia. By E. Le G. Troughton.

NOTES AND EXHIBITS.

Dr. W. L. Waterhouse exhibited specimens of F1 wheat plants showing the "dwarf" or "grass clump" character, together with flag smut infection. These have occurred in two of the crosses made last season. Dominance of susceptibility to flag smut has been shown in the F1 generation of a large number of crosses between vulgare wheats examined season after season, and this has been borne out by examinations of the F2 and F3 generations of the cross "Canberra" × "Red Rock." But the present instances are the first found in which dwarfs have been infected with flag smut.

Mr. G. P. Whitley remarked upon an interesting eighteenth-century systematic work on the Australian fauna. This was the *Systematische-Summarische Uebersicht der neuesten Zoologischen Entdeckungen in Neuholland und Afrika* by F. A. A. Meyer, published at Leipzig in 1793, a copy of which had been consulted in the Mitchell Library, Sydney. Apart from its historic interest, this booklet merited attention because binomial names were given therein to the mammals, birds, reptiles, fishes and arachnida described in the works of Phillip and White. Meyer seems to have been the first writer to give a scientific name to the Port Jackson Shark (*Squalus Portus Jacksoni*). What appears to be our local Soldier Crab was named *Cancer brachyurus* in Meyer's index, and the remaining groups of animals would perhaps repay study by taxonomists.

SPECIAL GENERAL MEETING.

29th July, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

On the motion of Mr. A. F. Basset Hull, seconded by Mr. D. G. Stead, the adoption of the proposed new Rule xiia, as follows, was carried unanimously:

> xiia.—The Council may admit persons, not more than twenty-five years of age, as Associates. Such persons may attend all or any General Meetings of the Society, but shall not be entitled to vote; they shall be entitled to use the library and reading-room, but not to borrow books; and they shall receive a copy of the Abstract, but not the Proceedings. Application for admission as an Associate shall be in writing, addressed to the Secretary, and shall contain the applicant's full name, address, and date of birth. Upon being notified of admission, the applicant shall pay a subscription of Ten Shillings for the then current year, and the same amount annually thereafter. Upon reach-

ing the age of twenty-five years every Associate must resign, or apply for admission as an Ordinary Member; provided that in special cases the Council may extend the term of Associateship for such period as the Council may think fit.

ORDINARY MONTHLY MEETING.

29th July, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

A letter was read from Mrs. Shaw, thanking the Society for sympathy extended to her on the death of her husband.

The President drew attention to the expected arrival of an expedition from Harvard University, under the leadership of Professor W. M. Wheeler, to collect entomological, zoological and ornithological material in Australia.

The Donations and Exchanges received since the previous Monthly Meeting (24th June, 1931) amounting to 39 Volumes, 262 Parts or Numbers, 10 Bulletins, 15 Reports and 6 Pamphlets, received from 108 Societies and Institutions and 2 private donors, were laid upon the table.

PAPERS READ.

1. On a new Bopyrid Parasite from the Coast of New South Wales. By Professor W. J. Dakin, D.Sc.

2. Notes on Australian Diptera. xxviii. By J. R. Malloch. (*Communicated by Dr. G. A. Waterhouse.*)

3. The Gasteromycetes of Australasia. xii. The genus *Scleroderma*. By G. H. Cunningham.

NOTES AND EXHIBITS.

Dr. C. Anderson, on behalf of the Trustees of the Australian Museum, exhibited a cast of the brain case of the Pekin Man, *Sinanthropus pekinensis*. The original was found in December, 1929, in a cave at Chou Kou Tien, near Pekin, by Mr. W. C. Pei, a young Chinese geologist. It belongs to the oldest Pleistocene and is of practically the same age as the Ape Man of Trinil, Java (*Pithecanthropus erectus*), and the Piltdown Man (*Eoanthropus dawsoni*) of Sussex, England. These are the three most primitive human types known, and the new find links the two older discoveries in an important manner, proving that Pekin Man was intermediate between the other two though generically distinct from both.

Mr. W. W. Froggatt exhibited blooms of *Acacia spectabilis*, which Mr. Cambage had called the Blue Wattle; a better name would be the Blue-stemmed Wattle. The seed was collected in the Pilliga Scrub where it grows as a shrubby spreading bush. Seeds planted some four years ago have sprung up into tall willowy trees, with slender stem up to fifteen feet in height, in the good clay soil of Croydon. It has a very beautiful bloom and foliage but on account of its height and slender stem is easily blown over, so it should be planted in a sheltered corner about Sydney.

Mr. A. H. S. Lucas showed (1) formalin specimens of *Avrainvillea papuana* grown on the sandy floor of the Lagoon, Low Island, with the long column of rhizoids stiffened by sand grains, (2) formalin specimens of *Trichodesmium scoboideum* Lucas, obtained from the open sea between Townsville and Mackay.

Dr. W. L. Waterhouse exhibited specimens of "Nodak," an American variety of *Triticum durum*, which was found growing in the Sydney University plots infected by *Tilletia tritici*, an organism causing "bunt" in wheat. This appears to be a first record of a durum wheat infected with bunt, and may indicate the advent of a new physiologic form of the causal organism.

Mr. A. N. Colefax exhibited (1) a specimen of *Lophiomus laticeps*, related to the Angler-fishes, and very rare along the New South Wales coast, but recorded from Queensland coast. This is apparently the second record for New South Wales, the first being by Mr. G. P. Whitley of a specimen trawled off the coast of New South Wales in 40 fathoms of water in March, 1927. The present specimen was trawled up by the Red Funnel trawler "Bar Ea Mul" in January, 1911, off Eden in 70 fathoms and has subsequently been taken again in the same spot; (2) a specimen of Burrowing Crab (*Ranina ranina*), trawled by the trawler "Bar Ea Mul" in 35 fathoms. It is not often found in these waters, being a definite tropical form. The tribe to which it belongs, the Oxystomata, generally live in sandy regions and burrow into the substratum. In correlation with the burrowing habit they exhibit many remarkable modifications to ensure that the stream of water taken into the gill chamber shall be free of sand grains. In this specimen the chelae are peculiarly modified and bear a thick line of bristles along their inner margins; they are held closely against the carapace which also bears bristles and the water is strained through these, reaching the gills in an uncontaminated condition. The flattened ends of the last walking legs are also suited to the burrowing habit.

In connection with the exhibit of the specimen of *Ranina* or Frog Crab, Mr. David G. Stead mentioned that a specimen which he had observed (and which had been captured by line off South Head in 60 fathoms of water) had progressed in two separate leaps in a frog-like manner when placed on a grass lawn.

The President (Professor T. G. B. Osborn) gave a short account (illustrated with lantern slides) of the work carried on at the Koonamore Vegetation Reserve.

SPECIAL GENERAL MEETING.

26th August, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

It was unanimously resolved that the adoption of the proposed new Rule XIIA, which had been unanimously carried at the Special General Meeting of 29th July, 1931, be confirmed.

ORDINARY MONTHLY MEETING.

26th August, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

Mr. William J. Lawrence, Carlton, was elected an Ordinary Member of the Society.

The President announced the receipt of a letter from the Under-Secretary for Lands notifying the gazettal of a National Recreation Reserve at Point Lookout embracing an area of 42,190 acres.

The President also announced that representatives of the Society had joined with representatives of other Societies in extending a welcome to members of the Expedition from the Museum of Comparative Zoology at Harvard who arrived in

Sydney on Tuesday, 18th August. The members of the Expedition left Sydney for Western Australia on 25th August, but it is hoped that we may have the pleasure of their attendance at a meeting of the Society on their return to Sydney.

The Donations and Exchanges received since the previous Monthly Meeting (29th July, 1931) amounting to 27 Volumes, 175 Parts or Numbers, 19 Bulletins, 2 Reports and 7 Pamphlets, received from 87 Societies and Institutions and 3 private donors, were laid upon the table.

PAPERS READ.

1. On the Autecology of *Stipa nitida*: a Study of a Fodder Grass in arid Australia. By T. G. B. Osborn, J. G. Wood and T. B. Paltridge.

2. The Gasteromycetes of Australasia. xiii. The Genus *Pisolithus*. By G. H. Cunningham.

3. Notes on Australian Diptera. xxix. By J. R. Malloch. (*Communicated by Dr. G. A. Waterhouse.*)

NOTES AND EXHIBITS.

Dr. A. B. Walkom exhibited the specimens and slides of *Clepsydropsis australis*, from Mt. Tangorin and Lyndon, near Eccleston, which had been described and figured by Professor Sahni (*Phil. Trans. Roy. Soc.*, Ser. B., Vol. 217, p. 1).

ORDINARY MONTHLY MEETING.

30th September, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

The President announced that the Council is prepared to receive applications for four Linnean Macleay Fellowships tenable for one year from 1st March, 1932, from qualified candidates. Applications should be lodged with the Secretary, who will afford all necessary information to intending candidates, not later than Wednesday, 4th November, 1931.

The President reminded members that the Fletcher Memorial Lecture for 1931 is to be delivered on Monday, 9th November, by Professor W. E. Agar, of the University of Melbourne.

The President referred to the death of Mr. A. A. Lawson, who had been a member of the Society since 1923.

The Donations and Exchanges received since the previous Monthly Meeting (26th August, 1931) amounting to 20 Volumes, 175 Parts or Numbers, 9 Bulletins, 3 Reports and 9 Pamphlets, received from 74 Societies and Institutions, were laid upon the table.

PAPERS READ.

1. Contributions to our Knowledge of the Actinomycetales. ii. The Definition and Subdivision of the Genus *Actinomyces*, with a Preliminary Account of Australian Soil Actinomycetes. By H. L. Jensen, Macleay Bacteriologist to the Society.

2. Revision of Australian Lepidoptera.—Supplementary. By A. Jefferis Turner, M.D., F.E.S.

3. The Wing-venation of the Order Isoptera. i. Introduction and the Family Mastotermitidae. By R. J. Tillyard, M.A., Sc.D., D.Sc., F.R.S.

NOTES AND EXHIBITS.

Dr. I. V. Newman exhibited some twigs of *Acacia Baileyana* bearing flowers that had been infected by an insect parasite. The flowers had not opened, but the petals had been stimulated to develop to such an extent that single flowers appeared to be the size of a normally unopened flower-head, the sepals remaining unaffected. The larva destroys the young carpel and the stamens before entering the pupal stage. The emerging fly often leaves the old skin protruding from the flower. The petals of the flower become very thick and remain green, with a tendency to be yellow at the tips. These infected flowers have remained on the tree, in a green condition, for more than six weeks after normal flower-heads had fallen off. The insect concerned is a species of *Cecidomyia*, a genus that attacks Acacias in many ways.

Mr. W. W. Froggatt exhibited a new coccid belonging to the *Lecanium* group, which had been sent to him by Mr. R. Veitch, of the Department of Agriculture, Brisbane. The coccid was found on the brigalow in Western Queensland, and it is a remarkable form that does not fit in with any of the known genera of the group.

Dr. A. B. Walkom exhibited (i) fertile specimens of the Mesozoic fern *Todites* from Turrimetta Head, Narrabeen, collected by Mr. S. W. Carey. This constitutes the first record of this genus from the Narrabeen Series. (ii) A very fine example of a winged seed collected by Mr. G. H. Blakemore at Sichon, on the west coast of Siam. The spread of the wings is just more than 6½ inches, and it probably belongs to one of the Bignoniaceae.

The President (Professor T. G. B. Osborn) gave a short account, illustrated with lantern slides, of some of the vegetation types shown on the new Vegetation Map of Australia compiled by Professor Prescott of Adelaide.

ORDINARY MONTHLY MEETING.

28th October, 1931.

Mr. E. Cheel, Vice-President, and afterwards Professor T. G. B. Osborn, D.Sc., F.L.S., President, in the Chair.

Mr. Alan Burges, Croydon, Mr. Paul S. Hossfeld, Canberra, and Mr. H. K. C. Mair, Collaroy Beach, were elected Ordinary Members of the Society.

Candidates for Linnean Macleay Fellowships, 1932–33, were reminded that Wednesday next, 4th November, is the last day for receiving applications.

The President reminded members that the Fletcher Memorial Lecture for 1931 will be delivered on Monday, 9th November, by Professor W. E. Agar of the University of Melbourne, the subject being "The Animal Mind".

A letter was read from Mrs. A. A. Lawson and family, returning thanks for sympathy.

The Donations and Exchanges received since the previous Monthly Meeting (30th September, 1931) amounting to 3 Volumes, 62 Parts or Numbers, 2 Bulletins, 1 Report and 4 Pamphlets, received from 51 Societies and Institutions, were laid upon the table.

PAPERS READ.

1. The Reaction of *Viminaria denudata* to increased Water Content of the Soil. By Lilian Fraser, B.Sc.

2. The Physiography of the Shoalhaven River Valley. vi. Nerriga. By F. A. Craft, B.Sc., Linnean Macleay Fellow of the Society in Geography.

3. Notes on Australian Marine Algae. vi. By A. H. S. Lucas, M.A., B.Sc.

NOTES AND EXHIBITS.

Mr. E. Cheel exhibited fresh specimens of the following species of *Callistemon*: *C. linearifolius* DC., *C. pallidus* Bonpl., *C. viminalis* (Sol.) Cheel, *C. lilacinus* Cheel, *C. lilacinus* var. *carmina* Cheel, *C. paludosus* F.v.M., *C. paludosus* var. *roseus* (Hort.), *C. lanceolatus* × *C. acuminatus*; and *C. acuminatus* Cheel for comparison with the above-mentioned hybrid. Specimens of two forms or species at present undescribed were also shown, together with examples of seedlings raised from the latter.

Mr. Cheel also exhibited specimens of *Leptospermum microphyllum* F.v.M., raised from seeds received from Victoria four years ago, which up to the present had not flowered. Although originally described as a distinct species, it is included as a synonym under *L. lanigerum* by Bentham. Flowering and fruiting specimens received from Victoria, as well as the foliage characters of the cultivated plant which are distinctly odoriferous and identical with the parent plant, show that it is abundantly distinct and should be regarded as a separate species.

ORDINARY MONTHLY MEETING.

25th November, 1931.

Professor T. G. B. Osborn, D.Sc., F.L.S., President, and afterwards Mr. E. Cheel, Vice-President, in the Chair.

The President announced that the Council had reappointed Miss Ida A. Brown, B.Sc., and Mr. Frank A. Craft, B.Sc., to Linnean Macleay Fellowships in Geology and Geography respectively for one year from 1st March, 1932; and had appointed Dr. H. Claire Weekes, D.Sc., and Miss Lilian R. Fraser, B.Sc., to Linnean Macleay Fellowships in Zoology and Botany respectively for a period of one year from 1st March, 1932.

The Donations and Exchanges received since the previous Monthly Meeting (28th October, 1931) amounting to 8 Volumes, 119 Parts or Numbers, 16 Bulletins, 4 Reports and 7 Pamphlets, received from 70 Societies and Institutions, were laid upon the table.

PAPERS READ.

1. A Classification of the Gall-making Coccids of the Genus *Apiomorpha*. By W. W. Froggatt, F.L.S.

2. The Stratigraphical and Structural Geology of the Devonian Rocks of the South Coast of New South Wales. By Ida A. Brown, B.Sc., Linnean Macleay Fellow of the Society in Geology.

3. Notes on New South Wales Orchids. By Rev. H. M. R. Rupp, B.A.

4. Note on the Leaf-buds of Angophoras. By Gladys Carey, B.Sc.

5. An Investigation of *Lobelia gibbosa* and *Lobelia dentata*. i. Mycorrhiza, Latex System and General Biology. By Lilian R. Fraser, B.Sc.

NOTES AND EXHIBITS.

Miss J. Vickery exhibited specimens of *Drosera peltata* Sm. which showed adventitious buds developing from the lamina of ordinary leaves. Some of these shoots had well developed foliage leaves, and "droppers" were growing towards the ground, so that they would almost certainly be capable of establishing themselves as separate plants. Specimens of *Drosera auriculata* Backh. were also exhibited, which had been growing in small patches of moss on steeply sloping rocks. Their "droppers" had grown downwards completely out of the soil, and their growing points had given rise to a group of foliage leaves in place of the usual tuber.

Dr. W. L. Waterhouse exhibited specimens of *Thalictrum flavum* and *T. dipterocarpon* showing the aecidial stage of *Puccinia triticina*. In tests extending over ten years this is the first season in which germination of the teleutospores has been obtained, and the successful infection of the alternate host opens up a new avenue of work dealing with the specialization of the rust. *T. dipterocarpon* is apparently a new record as a host of the rust.

Mr. E. Cheel exhibited specimens of *Telopea oreades* F.v.M., collected at Bombala, which are identical with the original specimens collected at Nangutta Creek and Weatherhead, Victoria. It is figured in Ewart's "Plants Indigenous to Victoria", Vol. ii, 1910, p. 10, Pl. 72, and in Curtis's "Botanical Magazine", 1916, tab. 8684. The Braidwood, N.S.W., specimens figured as *T. oreades* by Maiden in his "Forest Flora of New South Wales", Vol. v, 1913, p. 69, Pl. 163 (except the large leaf, fig. "N" from Gippsland, Victoria), are quite distinct from the typical species and, although somewhat approaching the Tasmanian species, *Telopea truncata* R.Br., appear to be sufficiently distinct from both *T. oreades* and *T. truncata*, and worthy of specific rank. Further investigations are being made (and, if possible, fresh flowers obtained during the present month, which is the flowering period) with a view of defining the differential characters of the three forms, all of which are distinct from the eastern *T. speciosissima*.

Mr. Cheel also exhibited fresh flowering specimens of *Leptospermum microphyllum* F.v.M., cultivated at Ashfield, raised from seeds collected at Lower Gellibrand River, Victoria, by the late H. B. Williamson in November, 1925. Fresh young foliage of this plant was exhibited at the October meeting, without any flower buds being visible. The rapid development of the buds and flowers is noteworthy, especially when compared with six years' period from seed germination to flowering stage. This species has also been collected at Studley Park, Victoria. Specimens of *L. lanigerum* Sm. were exhibited for comparison.

Mr. E. Cheel exhibited specimens of a Eucalypt with buds, flowers and fully developed fruits (the latter from last year's flowers) taken from a tree cultivated at Ashfield. The plant is one of several raised from seeds collected at Wyndham in June, 1916, which was cut in September, 1927, at four feet from the ground, the sapling measuring 19 feet 6 inches in length. From the stump two additional saplings were allowed to grow, which were again cut in September of this year. The length of the taller of the two saplings produced since September, 1927 (four years) measured 27 feet 5 inches, and the diameter just below the cut (i.e., the original stump) measured 10½ inches. The plant is a "Stringybark" form of Eucalyptus, determined by the late Mr. J. H. Maiden as *E. eugenioides*, but has larger fruits than the typical *E. eugenioides* found in the neighbourhood of Hurstville, Homebush, and other localities in the Port Jackson district. Mr. A. R. Penfold, Economic Chemist and Curator of the Technological Museum, has distilled

the essential oil from the leaves of the cultivated plant taken in September, 1927, and again in September, 1931, as well as from plants at Wyndham, and finds that the odour is pleasant and quite aromatic, whereas that from the Port Jackson plants is rank and not by any means pleasant. It is also interesting to note that a plant cultivated at Hill Top, on the Main Southern Line, 78 miles from Sydney, at an elevation of about 2,000 feet, from the same batch of seedlings is still alive, but is barely 2 feet high. The leaves are much smaller and retain the character of the seedling stage or reversionary shoots, but have the same characteristic odour as the mother plant from Wyndham and the seedling plants grown at Ashfield. The soil at Hill Top, however, is of an acid sandstone nature and is apparently quite unsuitable for this particular form of Eucalypt to thrive, and clearly shows the need for special study in connection with the soil requirements of certain forms of plants.

DONATIONS AND EXCHANGES.

Received during the period 27th November, 1930, to 25th November, 1931.

(*From the respective Societies, etc., unless otherwise mentioned.*)

ABERYSTWYTH.—*Welsh Plant Breeding Station, University College of Wales.* Imperial Bureau of Plant Genetics: Herbage Plants, Bulletin, No. 3; Leaflet Series S, No. 2; "The Welsh Journal of Agriculture", vii (1931).

ACCRA.—*Geological Survey of the Gold Coast.* Report on the Geological Survey Department for the Financial Year 1929-30 (1930).

ADELAIDE.—*Department of Mines: Geological Survey of South Australia.* Annual Report of the Director of Mines and Government Geologist for 1929 (1930); Mining Review for Half Year ended December 31st, 1930 (No. 53) (1931); Bulletin, No. 15 (1931).—*Field Naturalists' Section of the Royal Society of South Australia and South Australian Aquarium Society.* "The South Australian Naturalist", xii, 1-4 (1930-1931).—*Public Library, Museum and Art Gallery of South Australia.* Forty-seventh Annual Report of the Board of Governors, 1930-31 (1931); Records of the South Australian Museum, iv, 3 (1931).—*Royal Society of South Australia.* Transactions and Proceedings, liv (1930).—*South Australian Ornithological Association.* "The South Australian Ornithologist", xi, 1-4 (1931).—*University of Adelaide.* "The Australian Journal of Experimental Biology and Medical Science", vii, 4 (T.p. & c.) (1930); viii, 1-3 (1931).—*Woods and Forests Department.* Annual Report for the Year ended June 30th, 1930 (1931).

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ALGER.—*Institut Pasteur d'Algérie.* Archives, vii, 2-4 (T.p. & c.) (1929); viii, 1-4 (T.p. & c.) (1930).—*Société d'Histoire Naturelle de l'Afrique du Nord.* Bulletin, xxi, 1930, 6-9 (T.p. & c.) (1930); xxii, 1-7 (1931).

AMSTERDAM.—*Nederlandsche Entomologische Vereeniging.* Entomologische Berichten, viii, 175-180 (1930-1931); Tijdschrift voor Entomologie, lxxiii, 3-4 (T.p. & c.) (1930); lxxiv, 1-3 (1931); Verslagen van de Vergaderingen der Afdeeling Nederlandsch Oost-Indie van der Nederlandsche Entomologische Vereeniging, i, 1-2 (1931).

ANN ARBOR.—*University of Michigan.* Contributions from the Museum of Palaeontology, iii, 8 (1930); Miscellaneous Publications of the Museum of Zoology, Nos. 20-22 (1930-1931); Occasional Papers of the Museum of Zoology, Nos. 215, T.p. & c. for Nos. 198-215 (Vol. ix) (1930); 216-227 (1930-1931); Papers of the Michigan Academy of Science, Arts and Letters, xiii-xiv, 1930 (1931).

AUCKLAND.—*Auckland Institute and Museum.* Annual Report, 1930-31 (1931).

BALTIMORE.—*Johns Hopkins University.* Bulletin of the Johns Hopkins Hospital, xlvii, 1-6 (T.p. & c.) (1930); xlviii, 1-6 (T.p. & c.) (1931); xlix, 1-4 (1931); University Circular, N.S. 1906, Nos. 6, 8 (1906); 1930, 10-12 (1930); 1931, 1-2, 4-9 (1931).—*Geological Laboratory.* General Report of the Maryland Geological Survey, xii (1928); Maryland Geological Survey, Baltimore County, with Maps in portfolio (1929).

BANDOENG.—*Opsporingsdienst Dienst van den Mijnbouw in Nederlandsch-Indië.* Bulletin of the Netherlands East Indian Volcanological Survey, Nos. 35-48 (1930-1931); Publications of the Mining and Geological Survey Department in the Dutch East Indies during 1910-1930 (April, 1931); Wetenschappelijke Mededeelingen, Nos. 16-18 (1931).

BARCELONA.—*Junta de Ciencias Naturals de Barcelona.* Cataleg de les Publicacions (1930).—*Real Academia de Ciencias y Artes de Barcelona.* Boletin, vi, 2 (1931); Memorias, xxii, 2-16 (1930-1931); Nomina del Personal Academico, 1930-1931 (1930).

BATAVIA.—*Natuurwetenschappelijke Raad voor Nederlandsch-Indië te Batavia* (Netherlands Indies Science Council). Publication No. 4 (Mei, 1931).

BERGEN.—*Bergens Museum.* Arbok, 1930, 2 (T.p. & c.) (1931); Arsberetning, 1929-1930 (1930).

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BERLIN.—*Botanische Garten und Museum.* Notizblatt, xi, 101-103 (1930-1931).—*Deutsche Entomologische Gesellschaft, E.V.* Deutsche Entomologische Zeitschrift, 1930, 2-4 (1930-1931); Mitteilungen, i, 7-10 (T.p. & c.) (1930); ii, 1-5 (1931).—*Notgemeinschaft der Deutsche Wissenschaft.* "Flora", Neue Folge, xxv, 1-2 (1930-1931).—*Zoologische Museum.* Mitteilungen, xvi, 3-6 (T.p. & c.) (1930); xvii, 1-3 (1931).

BERN.—*Naturforschende Gesellschaft.* Mitteilungen a.d. Jahre 1930 (1931); Verhandlungen, 111, Jahresversammlung (1930).

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BLOEMFONTEIN.—*Nationale Museum.* Paleontologiese Navorsing, i, 2 (1931).

BOLOGNA.—*Laboratorio di Entomologia del R. Instituto Superiore Agrario di Bologna.* Bollettino, iii (1930).

BOMBAY.—*Bombay Natural History Society.* Journal, T.p. & c. for xxxiv, Nos. 1-2 (1931); xxxiv, 3-4 (T.p. & c.) (1930-1931); xxxv, 1-2 (1931).

BONN.—*Naturhistorische Verein der Preussische Rheinlande und Westfalens.* Sitzungsberichte, 1929 (1931); Verhandlungen, lxxxvi, 1929 (1930).

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BRISBANE.—*Australian and New Zealand Association for the Advancement of Science* (formerly *Australasian Association for the Advancement of Science*). Report of the Twentieth Meeting, Brisbane, 1930 (1931).—*Department of Agriculture.* Queensland Agricultural Journal, xxxiv, 1-6 (T.p. & c.) (1930); xxxv, 1-6 (T.p. & c.); xxxvi, 1-5 (1931).—*Great Barrier Reef Committee.* Reports, iii (1931).—"*Queensland Government Mining Journal*" (*from the Editor*), xxxi, Dec., 1930 (T.p. & c.) (1930); xxxii, Jan.-Nov., 1931 (1931).—*Queensland Naturalists' Club and Nature-Lovers' League.* "The Queensland Naturalist", vii, 6 (1931).—*Royal Society of Queensland.* Proceedings, xlii, 1930 (1931).

BRNO.—*Prirodovedecka Fakulta, Masarykovy University.* Spisy (Publications) (Botanical only), Cis. 128 (1930).

BROOKLYN.—*Botanical Society of America.* "American Journal of Botany", xvii, 8-10 (T.p. & c.) (1930); xviii, 1-7 (1931).—*Brooklyn Institute of Arts and Sciences: The Museum.* Science Bulletin, iv, 1 (1930).

BRUSSELS.—*Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique.* Annuaire, 97e Année (1931); Bulletin de la Classe des Sciences, 1930, 3-12 (T.p. & c.) (1930); 1931, 1-2 (1931).—*Musée Royal d'Histoire Naturelle de Belgique.*—Bulletin, vi, 5-21 (1930); Mémoires, 41-43, 45, 46 (1930); Hors Série (Résultats Scientifiques du Voyage aux Indes Orientales Néerlandaises), ii, 2-5; iii, 1-3; v, 1 (1930); "Notes Preliminaires sur les Opilions, etc." by L. Giltay and "Notes Preliminaires sur les Phasmides" and "Notes Preliminaires sur les Mantides" by F. Werner (From *Bull. and Ann. Soc. Ent. Belg.* lxix, 1929 and lxx, 1930).—*Société Entomologique de Belgique.* Bulletin and Annales, lxx, 9-12 (T.p. & c.) (1930); lxxi, 1-8 (1931); Mémoires, xxiii, 1, 4-5 (T.p. & c.) (1930-1931).—*Société Royale des Sciences de Liége.* Mémoires, 3e Série, xv (1930).—*Société Royale Zoologique de Belgique.* Annales, lx, 1929 (1930).

BUDAPEST.—*Musée National Hongrois.* Annales Historico-Naturales, xxvi, 1929 (1930).

BUENOS AIRES.—*Museo Nacional de Historia Natural.* Anales, xxxvi (1929-1931).—*Sociedad Argentina de Ciencias Naturales.* Revista "Physis", x, 35-36 (1930-1931).

BUITENZORG.—*Department van Landbouw, Nijverheid, en Handel.* Bulletin du Jardin Botanique, Serie iii, xi, 2 (1931); "Treubia", xii, 3-4 (T.p. & c.) and Supplement (1930-1931); xiii, 1-2 (1931).

CAEN.—*Société Linnéenne de Normandie.* Bulletin, 7e Série, ix, 1926 (1928); 8e Série, ii, 1929 (1930); Mémoires, Nouvelle Série, Section Géologique, i, 1 (1930).

CALCUTTA.—*Geological Survey of India.* Memoirs, lvi (1930); lviii (1931); Memoirs, Palaeontologia Indica, N.S. ix, 2, Pts. 4-5 (1931); xi, 2 (1931); xv, 1-8 (1930); xvii (1931); xix (1931); Records, lxiii, 3-4 (T.p. & c.); lxiv (1930); lxv, 1 (1931).—*Indian Museum.* Memoirs, ix, 5; xi, 1 (1930); Records, xxiii, 2 (1931); xxxi, Appendix and T.p. & c. (1930); xxxii, 2-4, Appendix and T.p. & c. (1930-1931); xxxiii, 1 (1931).

CAMBRIDGE, England.—*Cambridge Philosophical Society.* Biological Reviews and Biological Proceedings, vi, 1-3 (1931); Transactions, T.p. & c. for xxiii, 1923-1928 (1931).

CAMBRIDGE, Mass.—*Museum of Comparative Zoology at Harvard College.* Annual Report of the Director for 1929-1930 (1930); Bulletin, lv, 6 (T.p. & c.) (1921); lxxi, 1-6 (T.p. & c.) (1930-1931); lxxii, 1 (1931); Revised Price List of Publications (February, 1931).

CANBERRA.—*Commonwealth Bureau of Census and Statistics.* Official Year Book, No. 23, 1930 (1930).—*Council for Scientific and Industrial Research.* Fourth Annual Report for the Year ended 30th June, 1930 (1930).

CANTON.—*Botanical Institute, College of Agriculture, Sun Yatsen University.* "Sunyatsenia", i, 1 (1930).—*Geological Survey of Kwangtung and Kwangsi.* Annual Report, ii, 2, 1928-1929 (1929); iii, 1929-1930, 1 (1930); Palaeontological Memoir, i, 1-2 (1930); Special Publication, No. 6 (1930).

CAPE TOWN.—*Royal Society of South Africa.* Transactions, xix, 1-4 (T.p. & c.) (1930-1931).—*South African Museum.* Annals, xxix, 2 (T.p. & c.) (1931); Report for the Year ended 31st December, 1930 (1931).

CHICAGO.—*Field Museum of Natural History.* "Abyssinian Birds and Mammals", painted from life by Louis Agassiz Fuertes (32 reproductions in portfolio) (1930); Leaflet: Botany, 15-16 (1930); Geology, 9 (1927); Publications: Botanical Series, iii, 3 (T.p. & c.) (1930); T.p. & c. for iv; vii, 2-3, viii, 1-5 (1930-1931); ix, 1-2; x; xi, 1 (1930-1931); Geological Series, iv, 4 (1925); Report Series, viii, 2 (T.p. & c.) (1931); Zoological Series, v-vi (1904-1905); vii, 1-13 (T.p. & c.) (1905-1912); viii-ix (1907-1909); x, 1-16 (T.p. & c.) (1909-1923); xi (1912); xii, 1-7 (1917-1924); xiii, pt. 2, Nos. 1-2; pt. 3 (1918-1919, 1924); xiv, 2 (1924); xvii, 7 (T.p. & c.) (1930-1931); xviii, 2-4 (1931).—*John Crerar Library.* xxxvith Annual Report for the Year 1930 (1931).

CHRISTCHURCH.—*Canterbury Museum.* Records, iii, 6 (1931).

CINCINNATI.—*Lloyd Library.* Bulletin, Nos. 28-30 (1928, 1930, 1931); Circular, Nos. 1-5 (no date—1925); Letter, Nos. 6, 9-69 (1905-1919); Puff Ball Letter, No. 5 (1905); "Synopsis of the Genus Fomes" and "Synopsis of the Cordyceps of Australasia" by C. G. Lloyd (1915); Title page only to Bibliographical Contributions, Vol. iii, Nos. 1-7 (1917-1918); Index of the Mycological Writings, Vols. i-vii (1898-1925).

CLUJ.—*Gradina Botanica.* Bulletin, x, Appendix 1 (1930).

COIMBRA.—*Universidade de Coimbra: Museu Zoologico.* Arquivos da Seccao de Biologia e Parasitologia, i, 1-3 (1929-1930); Memorias e Estudios, Serie i, 1, Fasc. 5; 29, Fasc. 2; 38-40 (1929).

COLD SPRING HARBOR.—*Department of Genetics: Carnegie Institution of Washington.* Annual Report of the Director, 1929-1930 (Extracted from Year Book No. 29, 1929-1930) (1930).

COLOMBO.—*Colombo Museum.* Spolia Zeylanica (Ceylon Journal of Science, Section B—Zoology and Geology), xvi, 2 (1931).

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COPENHAGEN.—*Det Kongelige Danske Videnskabernes Selskab.* Biologiske Meddelelser, ix, 3-4 (T.p. & c.) (1930); x, 1-2 (1930-1931).—*Zoological Museum of the University.* The Danish Ingolf-Expedition, iii, 11 (1931).

DUBLIN.—*Royal Dublin Society.* Scientific Proceedings, N.S. xix, 40-47 (T.p. & c.) (1930-1931); xx, 1-12 (1931).—*Royal Irish Academy.* Proceedings, xxxix, Section B, 16-28 (1930-1931); xl, Section B, 1-3 (1931).

EAST LANSING.—*Michigan State College of Agriculture and Applied Science.* "Brucellosis. i." by I. F. Huddleson and H. W. Johnson (From *Journ. Amer. Med. Assoc.*, 94, 1930, pp. 1905-1907) (1930); "Studies in the Pathology of Avian Coccidiosis" by H. J. Stafseth (From *Journ. Amer. Vet. Med. Assn.*, lxxviii, N.S. 31, No. 6, June, 1931); Reports of the Veterinary Division for the Years ending June 30, 1929, and June 30, 1930 (no dates).

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WORMLEY.—*The Hill Museum.* Bulletin, iv, 2 (1930).

Private Donors (and Authors, unless otherwise stated).

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Meyrick, E., B.A., F.R.S., Marlborough, Wilts, England.—"Exotic Microlepidoptera", iii, 18-20 (Index) (1930).

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Stead, David G., Sydney (donor).—*U.S. Department of the Interior: National Park Service.* Annual Report of the Director for Fiscal Year ended June 30, 1930 (1930).

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Vanderbilt, W. K., 230 Park Avenue, New York, U.S.A. (donor).—Bulletin of the Vanderbilt Marine Museum, Vols. ii-iii (1930).

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LIST OF MEMBERS, 1931.

ORDINARY MEMBERS.

1927 *Albert, Michel François, "Boomerang", Elizabeth Bay, Sydney.
1929 Allan, Miss Catherine Mabel Joyce, Australian Museum, College Street, Sydney.
1905 Allen, Edmund, c/o Mulgrave Mill, Gordonvale, Queensland.
1906 Anderson, Charles, M.A., D.Sc., Australian Museum, College Street, Sydney.
1922 Anderson, Robert Henry, B.Sc.Agr., Botanic Gardens, Sydney.
1899 Andrews, Ernest Clayton, B.A., F.G.S., 32 Benelong Crescent, Bellevue Hill.
1929 Angell, Herbert Raleigh, Ph.D., Council for Scientific and Industrial Research, Canberra, F.C.T.
1927 Armstrong, Jack Walter French, "Callubri", Nyngan, N.S.W.
1912 Aurousseau, Marcel, B.Sc.

1913 Badham, Charles, M.B., Ch.M., B.Sc., Bureau of Microbiology, 93 Macquarie Street, Sydney.
1888 Baker, Richard Thomas, The Crescent, Cheltenham.
1925 Barnard, Colin, M.Sc., Council for Scientific and Industrial Research, Division of Plant Industry, Box 109, Canberra, F.C.T.
1919 Barnett, Marcus Stanley, c/o Colonial Sugar Refining Co., Ltd., O'Connell Street, Sydney.
1907 Benson, Professor William Noel, B.A., D.Sc., F.G.S., University of Otago, Dunedin, N.Z.
1920 Blakely, William Faris, Botanic Gardens, Sydney.
1929 Boardman, William, Australian Museum, College Street, Sydney.
1923 Bone, Walter Henry, 6 Deans Place, Sydney.
1926 Branch, Kenneth James Fergus, B.Sc., 99 North Steyne, Manly.
1912 Breakwell, Ernest, B.A., B.Sc., Department of Education, Box 33A, G.P.O., Sydney.
1927 Bredero, William Adrien Lewis, Box 127, Post Office, Orange, N.S.W.
1912 Brewster, Miss Agnes A., 481 Alfred Street, North Sydney.
1923 Brough, Patrick, M.A., B.Sc., B.Sc.Agr., "Kinross", Billyard Avenue, Wahroonga.
1921 Brown, Horace William, 871 Hay Street, Perth, W.A.
1924 Brown, Miss Ida Alison, B.Sc., Geology Department, The University, Sydney.
1911 Browne, William Rowan, D.Sc., Geology Department, The University, Sydney.
1931 Burges, Alan, 35 Wetherell Street, Croydon.
1920 Burkitt, Professor Arthur Neville St. George Handcock, M.B., B.Sc., Medical School, The University, Sydney.
1921 Burns, Alexander Noble, "Meringa", Fuchsia Street, Blackburn, Victoria.
1910 Burrell, Harry, 19 Doncaster Avenue, Kensington.
1910 Burrell, Mrs. Harry, 19 Doncaster Avenue, Kensington.
1926 Busacott, James Hardie, Meringa (private bag), via Cairns, North Queensland

1901 Campbell, John Honeyford, I.S.O., M.B.E., Royal Mint, Ottawa, Canada.
1927 Campbell, Thomas Graham, "Burrandong", 101 Lauderdale Avenue, Manly.
1930 Carey, Miss Gladys, B.Sc., 32 Rawson Street, Epping.
1905 Carne, Walter Mervyn, Senior Plant Pathologist, Division of Economic Botany, Council for Scientific and Industrial Research, c/o Department of Agriculture, Perth, W.A.
1903 Carter, Herbert James, B.A., F.E.S., "Garrawillah", Kintore Street, Wahroonga.
1899 Cheel, Edwin, Botanic Gardens, Sydney.
1924 Chisholm, Edwin Claud, M.B., Ch.M., Comboyne, N.S.W.
1901 Cleland, Professor John Burton, M.D., Ch.M., The University, Adelaide, S.A.

* Life Member.

1930 Cochran, William Manning Patrick, B.A., c/o Messrs. W. R. Carpenter & Co., Ltd., Rabaul, New Guinea.
1931 Colefax, Allen N., B.Sc., Department of Zoology, Sydney University.
1908 Cotton, Professor Leo Arthur, M.A., D.Sc., Geology Department, The University, Sydney.
1928 Craft, Frank Alfred, B.Sc., "Kyla", 24 Fourth Street, Ashbury.
1900 Crago, William Henry, M.D., 185 Macquarie Street, Sydney.
1925 Cunningham, Gordon Herriot, Ph.D., Department of Agriculture, Fields Division, Plant Research Station, P.O. Box 442, Palmerston North, N.Z.

1929 Dakin, Professor William John, D.Sc., Department of Zoology, The University, Sydney.
1885 David, Sir Tannatt William Edgeworth, K.B.E., C.M.G., D.S.O., M.A., D.Sc., F.R.S., Burdett Street, Hornsby.
1930 Davies, Professor Harold Whitridge, M.B., B.S., Department of Physiology, Sydney University.
1929 Deane, Cedric, A.M.I.E.Aust., "Cloyne", 9 State Street, Malvern, Victoria.
1925 de Beuzeville, Wilfred Alexander Watt, J.P., "Melamere," Welham Street, Beecroft.
1928 Dickson, Bertram Thomas, B.A., Ph.D., Council for Scientific and Industrial Research, Division of Plant Industry, Box 109, Canberra, F.C.T.
1881 Dixson, Thomas Storie, M.B., Ch.M., 215 Macquarie Street, Sydney.
1927 *Dixson, William, "Merridong", Gordon Road, Killara.
1921 Dodd, Alan Parkhurst, Prickly Pear Laboratory, Sherwood, Brisbane, Q.
1926 Dumigan, Edward Jarrett, West End Boys' School, West End, South Brisbane, Queensland.
1920 Dwyer, Rt. Rev. Joseph Wilfrid, Bishop of Wagga, Wagga Wagga, N.S.W.

1931 Edmonds, Miss Enid Mary, B.Sc., Department of Zoology, Sydney University.
1930 English, Miss Kathleen Mary Isabel, B.Sc., March Street, Yass, N.S.W.
1914 Enright, Walter John, B.A., West Maitland, N.S.W.

1908 Flynn, Professor Theodore Thomson, D.Sc., Queen's University, Belfast, Ireland.
1927 Francis, William Douglas, Botanic Gardens, Brisbane, Queensland.
1930 Fraser, Miss Lilian Ross, B.Sc., "Hopetoun," Bellamy Street, Pennant Hills.
1911 Froggatt, John Lewis, B.Sc., Department of Agriculture, Rabaul, New Guinea.
1886 Froggatt, Walter Wilson, F.L.S., Young Street, Croydon.
1930 Fuller, Miss Mary Ellen, B.Sc., Council for Scientific and Industrial Research, Box 109, Canberra, F.C.T.

1912 Goldfinch, Gilbert M., "Lyndhurst", Salisbury Road, Rose Bay.
1911 Greenwood, William Frederick Neville, F.L.S., F.E.S., c/o Colonial Sugar Refining Co., Ltd., Lautoka, Fiji.
1910 Griffiths, Edward, B.Sc., Department of Agriculture, Raphael Street, Sydney.
1901 Gurney, William Butler, B.Sc., F.E.S., Department of Agriculture, Raphael Street, Sydney.

1911 Hacker, Henry, F.E.S., Queensland Museum, Bowen Park, Brisbane, Q.
1925 Hale, Herbert Matthew, South Australian Museum, Adelaide, S.A.
1919 Hall, Leslie Lionel, "Haldor", Drumalbyn Road, Bellevue Hill.
1897 Halligan, Gerald H., F.G.S., "Geraldine", Culworth Avenue, Killara.
1885 Hamilton, Alexander Greenlaw, "Tanandra", Hercules Street, Chatswood.
1928 Hamilton, Edgar Alexander, 16 Hercules Street, Chatswood.
1931 Hamilton, Harold Wynne, 5 Eurella Street, Burwood.
1922 Hardwick, Frederick George, B.D.S., D.D.Sc., "Wyoming", 175 Macquarie Street, Sydney.
1917 Hardy, G. H. Hurlstone, The University, Brisbane, Q.
1911 Haviland, The Venerable Archdeacon F. E., St. Stephen's Rectory, Portland, N.S.W.
1930 Heydon, George Aloysius Makinson, M.B., Ch.M., School of Public Health and Tropical Medicine, The University, Sydney.

* Life Member.

1930 Holmes, Professor James Macdonald, B.Sc., F.R.G.S., Department of Geography, The University, Sydney.
1907 Hull, Arthur Francis Basset, Box 704, G.P.O., Sydney.
1892 Hynes, Miss Sarah, B.A., "Isis", Soudan Street, Randwick.

1912 Irby, Llewellyn George, Forestry Department, Hobart, Tasmania.

1917 Jacobs, Ernest Godfried, "Cambria", 106 Bland Street, Ashfield.
1930 Jensen, Hans Laurits, Department of Agriculture, The University, Sydney.
1907 Johnston, Professor Thomas Harvey, M.A., D.Sc., F.L.S., The University, Adelaide, S.A.
1930 *Joplin, Miss Germaine Anne*, B.Sc., "Huyton", Wentworth Street, Eastwood.
1930 Julius, Sir George Alfred, B.Sc., B.E., M.I.Mech.E., M.I.E.Aust., 67 Castlereagh Street, Sydney.

1923 Kendall, Mrs. W. M., M.Sc. (née Williams), 5 Queen Victoria Street, Drummoyne.
1924 Kinghorn, James Roy, Australian Museum, College Street, Sydney.

1931 Lawrence, William James, B.Sc., A.S.T.C., 56 Mill Street, Carlton.
1892 Lea, Arthur M., F.E.S., 241 Young Street, Unley, Adelaide, S.A.
1923 Lindergren, Gustaf Mauritz, Secretary, Swedish Chamber of Commerce, Pacific House, 249 George Street, Sydney.
1893 Lucas, Arthur Henry Shakespeare, M.A., B.Sc., "Girrahween", William Street, Roseville.

1922 Mackerras, Ian Murray, M.B., Ch.M., B.Sc., Box 109, Canberra, F.C.T.
1911 Mackinnon, Ewen, B.Sc., Commonwealth Department of Health, Civic Centre, Canberra, F.C.T.
1931 *Mair, Herbert Knowles Charles, "Playa Ancha", Collaroy Street, Collaroy Beach.
1929 Mann, John, Commonwealth Prickly Pear Board, Field Station, Box 49, Post Office, Chinchilla, Queensland.
1905 Mawson, Sir Douglas, D.Sc., B.E., F.R.S., The University, Adelaide, S.A.
1919 McCarthy, Timothy, Department of Agriculture, Raphael Street, Sydney.
1907 McDonnough, Thomas, L. S., "Iluka", Hamilton Street, Randwick.
1927 McHugh, Miss Mary Virgilius, St. Vincent's College, Potts Point, Sydney.
1917 McKeown, Keith Collingwood, Australian Museum, College Street, Sydney.
1927 McKie, Rev. Ernest Norman, B.A., The Manse, Guyra, N.S.W.
1919 McLuckie, John, M.A., D.Sc., Botany Department, The University, Sydney.
1925 McNeill, Francis Alexander, Australian Museum, College Street, Sydney.
1925 Mitchell, Miss Dora Enid, B.Sc., "Wilga", Bradley Street, Goulburn.
1930 Munch-Petersen, Erik, Ph.B., M.Sc. (Haunensis), M.I.F., 31 Lytton Street, North Sydney.
1926 Mungomery, Reginald William, c/o Sugar Experiment Station, Bundaberg, Queensland.
1922 Murray, Patrick Desmond Fitzgerald, D.Sc.
1920 Musgrave, Anthony, F.E.S., Australian Museum, College Street, Sydney.

1925 Newman, Ivor Vickery, M.Sc., Ph.D., "Tip Tree", Kingsland Road, Strathfield.
1913 Newman, Leslie John William, F.E.S., "Walthamstowe", 5 Bernard Street, Claremont, W.A.
1922 Nicholson, Alexander John, D.Sc., F.E.S., Council for Scientific and Industrial Research, Box 109, Canberra, F.C.T.
1920 Noble, Robert Jackson, B.Sc.Agr., Ph.D., Department of Agriculture, Raphael Street, Sydney.
1912 North, David Sutherland, c/o Colonial Sugar Refining Co., Ltd., Broadwater Mill, Richmond River, N.S.W.

1920 O'Dwyer, Margaret Helena, B.Sc., Ph.D., Forest Products Research Laboratory, Princes Risborough, Bucks., England.
1927 Oke, Charles George, 56 Chaucer Street, St. Kilda, Victoria.
1910 Oliver, Walter Reginald Brook, F.L.S., F.Z.S., Dominion Museum, Wellington, N.Z.

* Life Member.

1927 Osborn, Professor Theodore George Bentley, D.Sc., F.L.S., Department of Botany, The University, Sydney.
1921 Osborne, George Davenport, D.Sc., Geology Department, The University, Sydney.

1922 Perkins, Frederick Athol, B.Sc.Agr., Biology Department, University of Queensland, Brisbane, Q.
1921 Phillips, Montagu Austin, F.L.S., F.E.S., 57 St. George's Square, London, S.W., England.
1920 Pincombe, Torrington Hawke, B.A., "Mulyan", Beta Street, Lane Cove, Sydney.
1918 Priestley, Professor Henry, M.D., Ch.M., B.Sc., Medical School, The University, Sydney.
1924 Pritchard, Denis Adrian, M.B., Ch.M., B.Sc., Royal Australian Naval College, Jervis Bay, N.S.W.
1910 Pulleine, Robert Henry, M.B., Ch.M., 163 North Terrace, Adelaide, S.A.

1929 Raggatt, Harold George, B.Sc., Geological Survey, Department of Mines, Sydney.
1924 Roberts, Frederick Hugh Sherston, M.Sc., Department of Agriculture and Stock, Brisbane, Queensland.
1925 Roughley, Theodore Cleveland, Technological Museum, Harris Street, Sydney.
1927 Rupp, Rev. Herman Montagu Rucker, B.A., St. Mary's Rectory, Weston, N.S.W.

1919 *Scammell, George Vance, B.Sc., "Melrose", 28 Middle Head Road, Mosman.
1928 Selby, Miss Doris Adeline, M.Sc., "Marley", Werona Avenue, Gordon.
1930 Sherrard, Mrs. Kathleen Margaret, M.Sc., 16 Shellcove Road, Neutral Bay.
1887 Sloane, Thomas G., F.E.S., Moorilla, Young, N.S.W.
1909 Smith, G. P. Darnell, D.Sc., F.I.C., F.C.S., Botanic Gardens, Sydney.
1928 Smith, Jacob Harold, M.Sc., N.D.A., Court House, Cairns, N. Queensland.
1928 Smith, Thomas Hodge, Australian Museum, College Street, Sydney.
1916 Smith, Miss Vera Irwin, B.Sc., F.L.S., 13 Upper Cliff Road, Northwood.
1926 Stanley, George Arthur Vickers, B.Sc., "Clelands", Battery Street, Randwick.
1898 Stead, David G., "Boongarre", Pacific Street, Watson's Bay.
1905 Stokes, Edward Sutherland, M.B., Ch.M., Metropolitan Water, Sewerage and Drainage Board, 341 Pitt Street, Sydney.
1911 *Sulman, Miss Florence, "Burrangong", McMahon's Point.
1904 Sussmilch, C. A., F.G.S., East Sydney Technical School, Darlinghurst, Sydney.

1930 Taylor, Frank Henry, School of Public Health and Tropical Medicine, The University, Sydney.
1904 Tillyard, Robin John, M.A., D.Sc., F.R.S., F.L.S., F.E.S., C.M.Z.S., Chief Commonwealth Entomologist, Canberra, F.C.T.
1921 *Troughton, Ellis Le Geyt, Australian Museum, College Street, Sydney.
1902 Turner, A. Jefferis, M.D., F.E.S., Wickham Terrace, Brisbane, Q.
1904 Turner, Rowland E., F.Z.S., F.E.S., c/o Standard Bank of South Africa, Adderley Street, Cape Town, South Africa.

1917 Veitch, Robert, B.Sc., F.E.S., Department of Agriculture, Brisbane, Queensland.
1930 Vickery, Miss Joyce Winifred, 6 Coventry Road, Homebush.

1900 Walker, Commander John James, M.A., F.L.S., F.E.S., R.N., "Aorangi", Lonsdale Road, Summertown, Oxford, England.
1909 Walkom, Arthur Bache, D.Sc., Science House, Gloucester and Essex Streets, Sydney.
1930 Ward, Melbourne, "Bellevue Gardens", Wylde Street, Potts Point, Sydney.
1911 Wardlaw, Henry Sloane Halcro, D.Sc., Physiology Department, The University, Sydney.
1926 Waterer, Arthur S., 2 Dickson Street, Haberfield.
1897 *Waterhouse, G. Athol, D.Sc., B.E., F.E.S., Science House, Gloucester and Essex Streets, Sydney.
1928 Waterhouse, Lionel Lawry, B.E., "Rarotonga", 42 Archer Street, Chatswood.
1927 Waterhouse, Walter Lawry, D.Sc.Agr., "Haselmere", Chelmsford Avenue, Roseville.
1911 Watt, Professor Robert Dickie, M.A., B.Sc., University of Sydney.
1924 Wearne, Walter Loutit, "Telarah", Collingwood Street, Drummoyne.
1930 Webster, Miss Jessie Alice, B.Sc., "Chesterfield", 49 Bruce Street, Stanmore.

* Life Member.

1926 Weekes, Miss Hazel Claire, D.Sc., 30 Fairweather Street, Bellevue Hill.
1922 Welch, Marcus Baldwin, B.Sc., A.I.C., Technological Museum, Harris Street, Sydney.
1926 *Whitley, Gilbert Percy, Australian Museum, College Street, Sydney.
1926 Willings, Mrs. H., B.A. (née Wood), Council for Scientific and Industrial Research, Box 109, Canberra, F.C.T.
1903 Woolnough, Walter George, D.Sc., F.G.S., Canberra, F.C.T.
1925 Wright, Fred, c/o Messrs. Elliott Bros., Ltd., O'Connell Street, Sydney.
1929 Wright, George Henry, H.D.A., Public School, Barellan, N.S.W.
1910 Wymark, Frederick, 89 Castlereagh Street, Sydney.

HONORARY MEMBERS.

1923 Hill, Professor J. P., Institute of Anatomy, University of London, University College, Gower Street, London, W.C.1, England.
1923 Wilson, Professor J. T., LL.D., M.B., Ch.M., F.R.S., Department of Anatomy, the New Museums, Cambridge, England.

CORRESPONDING MEMBERS.

1888 Bale, W. M., F.R.M.S., 63 Walpole Street, Kew, Melbourne, Victoria.
1902 Broom, Robert, M.D., D.Sc., F.R.S., 38 Somerset Street, Grahamstown, South Africa.
1902 McAlpine, D., c/o Bank of New South Wales, Leitchville, Victoria.
1902 Meyrick, Edward, B.A., F.R.S., F.Z.S., Thornhanger, Marlborough, Wilts., England.

* Life Member.

INDEX.

(1931.)

(a) GENERAL INDEX.

(b) BIOLOGICAL INDEX.

New names are printed in SMALL CAPITALS.

FAMILY, GENERA AND SUBGENUS DESCRIBED AS NEW IN THIS VOLUME (1931).

CORRIGENDA.

Page 65, line 23, for *luteocornis* read *luteicornis*
Page 133, line 13, for *P. ophioglossa* read *Pterostylis ophioglossa*
Page 296, line 7, for *varicornis* read *varicolor*
Page 497, line 3, *after* Lilian Fraser, B.Sc. *add* Science Research Scholar in Botany, University of Sydney.

LIST OF PLATES.

PROCEEDINGS, 1931.

Date of issue.	Date of issue.	Date of issue.
12-4-39		
19.5-39		
25.11.39		
27.10.47		
18.6.59		
22.4.67		